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Claim-Evidence-Reasoning Strategy in a Project-Based Instruction: Effects on Horticulture Students' Critical Thinking Skills

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Abstract

This study investigated the effectiveness of integrating the Claim-Evidence-Reasoning (CER) framework with Project-Based Learning (PBL) to enhance the critical thinking skills of agricultural students. In the context of postharvest handling, where decision-making is often compromised by "invisible" biological consequences, this research utilized a quasi-experimental design involving 75 participants divided into an experimental group (n=38) and a control group (n=37). The experimental group was exposed to PBL combined with CER, while the control group utilized standard PBL alone. Both cohorts were evaluated across four domains: analysis, problem-solving, decision-making, and overall critical thinking. Statistical analysis using t-tests revealed that the experimental group achieved highly significant improvements across all variables (p<.05), with the overall critical thinking mean rising from 8.24 to 12.05. In contrast, the control group showed significant growth only in analysis and general critical thinking, failing to reach statistical significance in problem-solving (p=.208) and decision-making (p=.300). A comparison of post-test results confirmed a statistically meaningful performance gap between the two groups (p=.020), leading to the rejection of the null hypothesis for the experimental intervention.

The findings suggest that while traditional PBL fosters foundational knowledge, it is insufficient for developing the high-tier mastery required for complex technical dilemmas. This study underscores the necessity of "engineering" critical thinking into vocational curricula through structured argumentative models to move students from rote procedural application to expert-like professional judgment in agricultural logistics.

Keywords: Claim-Evidence-Reasoning (CER); Project-Based Learning; Critical Thinking; Postharvest Handling; Agricultural Education; Cognitive Scaffolding

1. Introduction

Learning is a fundamental process defined as a relatively permanent change in behavior resulting from experience. It began when a person encountered something new, whether through reading, listening, or actively trying to solve a problem. As per Prentice and Ott (2021), for the acquisition of knowledge to be successful, it needed to be an experience. This was echoed by Korucu-Kış (2021), who asserted that experiential learning took place when students intentionally broke down an experience, resulting in new information, skills, or insight. Through experiential learning, students were stimulated mentally, emotionally, and socially, which encouraged them to think critically, solve problems, and behave suitably in situations appropriate to their education.

Under the Philippine K–12 Education Curriculum, the Technology and Livelihood Education (TLE) module highly emphasized performance tasks, which accounted for 60% of a student's grade, as taken by Philippine Nikkei Jin Kai International School (2024) from DepEd's Grading System Order No. 8, s. 2015. These were oral work and demonstrations of skills that were intended to allow students to demonstrate practical skills and blend 21st-century competencies. This emphasis on project-based activities was counter to the conventional lecture method, which had been found in some research to not be as effective in bridging the gap between abstract concepts and practical application (Zhang & Ma, 2023). Work by Hasan et al. (2023) also indicated that project-based learning could be used to develop critical thinking and learning ability, a method based on experiential learning (Saugstad, 2012).

Critical thinking was an essential ability for all topics, both within and beyond the classroom. It allowed learners to solve problems, create and justify opinions, and make well-informed decisions. In the TLE curriculum, critical thinking was especially necessary for the use of life skills in schoolwork (Villegas, 2022). Diola et al. (2025) added that the Claim-Evidence-Reasoning (CER) approach was a strategy for building this ability since it promoted critical thinking and the support of claims by evidence and sound reasoning. Unfortunately, evidence showed that critical thinking was not well taught in most Philippine schools (Marquez, 2017). This called for effective strategies to enhance students' critical thinking skills. The research of Zhang and Ma (2023) revealed that experience-based learning, including problem-based and project-based learning, could be successful in sharpening these skills.

Since project-based learning had the potential to improve critical thinking and learning ability, this research investigated the added effect of using project-based learning with the CER strategy on a horticulture class. The researcher examined how the blended method affected the critical thinking ability and learning ability of Grade 10 learners. In investigating the strategic targeting of the CER strategy in a project-based learning setting, this research aimed to shed new light on its effectiveness and scope for enhancing student learning achievements.

1.1 Background of the Study

Learning was a complex process in which there was a relatively permanent change in behavior due to experience. This was the core of the notion of experiential learning, which posited that for knowledge to be gained, it had to be based on direct experience. According to Passarelli and Kolb (2023), experiential learning was when learners actively reflected on an encounter, resulting in new information, skills, or understanding. This pedagogical methodology, which encompassed several approaches like project-based learning and problem-based learning, invited learners to experience the content in their minds, hearts, and sociality. In the process, it encouraged them to be critical thinkers, problem solvers, and appropriate responders to actual circumstances. This was a sharp departure from the old, lecture method of pedagogy, which had been shown to be less efficient in helping bridge the theory-practice gap. Empirical studies showed that project-based learning, an experiential learning method, was useful in the development of critical thinking and learning ability (Issa & Khataibeh, 2021; Suteja & Setiawan, 2022).

In the Philippine K-12 Curriculum Education, however, Technology and Livelihood Education (TLE) was most appropriate for experiential learning, wherein performance tasks contributed significantly to the grade of the learner. Tasks like demonstrations of skills and group presentations were meant to enable learners to use what they had learned and acquire 21st-century skills. According to Shanta (2022), critical thinking was an essential skill for all subjects in academics and for real-world applications. It allowed students to examine information, make informed choices, and resolve complex issues. For TLE students, the skill was particularly vital for the transference of life skills to academic work. The Claim-Evidence-Reasoning (CER) approach was a systematic procedure that could be utilized to develop critical thinking. It called upon students to make a claim, evidence it, and provide an evidence-based logical explanation that connected the evidence to the claim. It prompted learners to think scientifically and critically.

Even as critical thinking was acknowledged internationally to be of prime importance, research underscored that it was not systematically taught in most Philippine institutions (Agenor & Luayon, 2024). This brought out a crucial research gap: although evidence existed showing that project-based learning could improve critical thinking and competence in learning, there was a need to explore further the effect of integrating project-based learning with definite, structured approaches such as CER (Buchman, 2024). The research aimed to do this by investigating how the implementation of the CER strategy in a project-based learning setting influenced students' critical thinking and learning ability in horticulture education.

According to a consolidated report on least learned competencies in TLE of Grade 10 of a certain school district in Buenavista, Quezon during the third quarter of the school year 2023-2024, it was found that most of the competencies listed in the report were identified as competencies that required students to perform and exhibit critical thinking skills in order for them to understand and attain the goals of the lessons. With this, the researcher aimed to employ CER and project-based instruction in teaching TLE and measured its impact on the critical thinking skills of the students.

This study was warranted by the necessity of finding successful teaching strategies to enhance students' performance in an environment that did not possess critical thinking skills, specifically within a subject such as TLE where this type of application was more crucial. Through investigating this particular type of teaching strategy blend, the study hoped to contribute new knowledge and a possible model for instructors who wanted to develop these critical skills within their students.

2. Methodology

This chapter outlines the research design, locale of the study, participants sampling technique, research instruments, data collection procedures and statistical treatment used in analyzing the data. Through these methodological approaches, the researcher established a structured framework for examining the relationship between the instructional strategy and the development of students’ critical thinking skills.

2.1 Research Design

This study utilized a quasi-experimental research design, specifically what is referred to as the Non-equivalent Control Group Design. This was particularly suitable in educational settings where the random assignment of individual students was impossible due to pre-existing, intact classroom structures (Creswell, 2014). This design differed from a true experiment in that it made use of two naturally occurring groups—in this case, two separate Grade 10 Horticulture classes—which acted as the experimental and control groups, respectively.

A Non-equivalent Control Group Design involved a structured Pre-test–Intervention–Post-test procedure as follows: At the start of the intervention, a pre-test was conducted on both groups in order to gain a pre-operational assessment of their critical thinking capabilities and learning abilities in post-harvest handling prior to the intervention of the independent variable.

In the intervention phase, both groups received varied instructional strategies: the experimental group was exposed to PBL integrated with the CER strategy, while the control group underwent a regular PBL curriculum without the explicitness of the CER framework. After the intervention, a post-test measured the gain in learning. The researcher used this design to statistically control for initial differences, isolate the specific effect of the CER strategy on the performance of students, and provide a strong framework for the effectiveness of the intervention.

2.2 Respondents of the Study

The respondents were all Grade 10 students enrolled in the Horticulture subject at Hagonghong Integrated High School during School Year 2025–2026. Instead of selecting individual students from different schools, the researcher utilized an intact group within the selected school. This sampling method was practical and appropriate, as it allowed the researcher to conduct the intervention in a natural classroom setting while representing the larger population within the District of Buenavista II.

2.3 Population and Sampling Technique

The specific sampling method used in this study was cluster sampling. The population of the study consisted of all public secondary schools within the District of Buenavista II offering Grade 10 Horticulture under the Technology and Livelihood Education (TLE) curriculum. From this population, Hagonghong Integrated High School was selected as the cluster for the study.

2.4 Data Gathering Procedures

The data gathering for this study followed a systematic and sequential process. After securing the necessary permission from the school principal of Hagonghong Integrated High School, the researcher coordinated with the Grade 10 Technology and Livelihood Education (TLE) teachers to identify two intact Grade 10 Horticulture sections within the school. Hagonghong Integrated High School was selected as the cluster representing the District of Buenavista II through cluster sampling.

The identified intact sections were designated as the control group and the experimental group. All Grade 10 students enrolled in the Horticulture subject in these sections during School Year 2025–2026 served as the respondents of the study. Initially, both groups were administered a pre-test designed to measure their critical thinking skills prior to the implementation of the intervention.

Following the pre-test, the experimental group underwent a Project-Based Learning curriculum integrated with the Claim-Evidence-Reasoning (CER) strategy for the duration of one academic quarter. Simultaneously, the control group was taught using Project-Based Learning alone, without the explicit instruction of the CER framework. At the conclusion of the intervention period, both groups were given an identical post-test to measure any changes in their critical thinking. The pre-test and post-test scores were then collected and meticulously organized for statistical analysis to determine the effectiveness of the intervention.

2.5 Research Instrument

The primary instrument for data collection in this study was a researcher-made survey questionnaire specifically designed to measure the critical thinking skills of Grade 10 students. The instrument was fundamentally structured around three distinct sections, each corresponding to a key component of critical thinking: Analysis, Problem-Solving, and Decision-Making.

To ensure the study's relevance and alignment with the actual timeline of implementation, the contextual focus of the questions was shifted from previous content to the Fourth Quarter's Horticulture competencies. Consequently, each question was directly contextualized within postharvest handling procedures, requiring students to demonstrate critical thought in scenarios related to differentiating types of maturity, explaining the principles of Tender Loving Care (TLC), and enumerating ways of reducing damage to produce.

To ensure the quality of this instrument, validity and reliability testing were both required. Content validity was established through a panel of experts who rigorously reviewed the questionnaire's items to confirm that they accurately measured the intended critical thinking skills and were appropriate for the Grade

10 target population. Following this, a reliability test was conducted by administering the survey to a group of students with similar characteristics to the study's participants. The reliability of the research instrument was evaluated using Cronbach's Alpha, a statistical measure that determines the internal consistency of a scale. For this study, the instrument achieved an overall coefficient of 0.810, which indicated a high level of reliability.

In the context of this study, the following ranges of scores, interpretations, and descriptions are utilized to assess student performance across three key domains. The assessment framework categorizes student performance into four distinct proficiency levels across the domains of analysis, problem-solving, and decision-making. Students achieve an Excellent rating with scores of 6 to 7, demonstrating thorough analytical evidence, creative and logical problem-solving, and well-justified decision-making. The Proficient level, ranging from 4 to 5, indicates a consistent ability to identify key relationships and suggests reasonable solutions with adequate justification. Scores between 2 and 3 represent the Developing stage, where students show partial analysis and limited evaluation, often missing deeper interpretations or providing unclear justifications. Finally, the Beginning level includes scores of 0 to 1, characterized by inaccurate analysis, a failure to identify core problems, and unsupported or inappropriate decisions.

2.6 Statistical Treatment of Data

The statistical analysis for this study was designed to achieve two primary objectives: to describe the characteristics of the data and to infer whether the intervention had a significant effect. This was accomplished through the use of both descriptive and inferential statistics.

Descriptive statistics were used to summarize and organize the data collected from the pre-test and post-test. For both the experimental group (PBL with CER) and the control group (PBL alone), the following were calculated:

- **Mean**: This represented the average score for each group on both the pre-test and post-test. The mean score provided a central tendency measure, giving a clear picture of the overall performance of each group before and after the intervention. For example, a higher mean score on the post-test suggested a general improvement in critical thinking or learning competence.
- **Standard Deviation**: This measured the amount of variation or dispersion of scores within each group. A low standard deviation indicated that the scores were clustered closely around the mean, suggesting a consistent level of performance among students in that group. A high standard deviation, on the other hand, indicated a wider spread of scores, suggesting a greater range of performance.

These descriptive statistics provided a foundational understanding of the data, allowing the researcher to see the basic performance trends within each group before and after the intervention.

Inferential statistics were used to make generalizations about the population based on the sample data. In this study, the primary inferential tool was the t-test, a statistical test used to determine if there was a significant difference between the means of two groups.

The study employed two types of t-tests:

- **Paired-Sample T-test**: This test was used to compare the pre-test and post-test scores within each group (the experimental group and the control group). This determined if there was a significant improvement in critical thinking and learning competence for the students in each group after the intervention.
- **Independent-Sample T-test**: This test was used to compare the post-test scores between the two groups (the experimental group and the control group). This was the most crucial part of the analysis as it directly answered the core research question: Did the group exposed to Project-Based Learning

with the CER strategy show a significantly greater improvement than the group taught with Project-Based Learning alone?

The results from these statistical analyses either supported or refuted the hypothesis that the CER strategy, when integrated into a Project-Based Learning framework, had a significant and positive effect on the critical thinking skills of horticulture students.

3. **Results and Discussions**

This chapter presents the tables showing the results of the data gathered which are analyzed and interpreted based on the statement and hypothesis sited.

The Pre-test and Post-test Scores of the Control Group Exposed to Project-Based Learning Alone Strategy and the Experimental Group Exposed to Project-Based Learning with the Claim-Evidence-Reasoning (CER) Strategy.

Table 1

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning Alone in terms of Analysis

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0.0	4	10.81	Excellent
4 – 5	11	29.73	19	51.35	Proficient
2 – 3	21	56.76	14	37.84	Developing
0 – 1	5	13.51	0	0.0	Beginning
Total	37	100.0	37	100.0	

The pre-test scores for the control group, consisting of 37 students exposed to Project-Based Learning alone, indicated a baseline level of analytical competence that was largely concentrated in the lower proficiency ranges. Out of the 37 participants, 0 student (0.00%) achieved a score of 6–7, 11 students (29.73%) achieved a score of 4–5, 21 students (56.76%) achieved a score of 2–3, and 5 students (13.51%) achieved a score of 0–1.

These results classified the students into the Excellent, Proficient, Developing, and Beginning categories, respectively. The data suggested that most students began the study with only a foundational ability to analyze maturity indices and draw valid conclusions regarding crop development. The 13.51% of students in the Beginning category indicated a significant struggle to differentiate between various maturity stages, while the total absence of students in the Excellent rating confirmed a lack of high-level mastery across the entire cohort. According to Priyadharsini (2025), true analysis requires the ability to see patterns and make inferences; the high percentage of students in the Developing category suggested that while they possessed factual knowledge, they had not yet achieved conceptual understanding. This is a common trend in traditional vocational settings where students learn the "how-to" of harvest but struggle with the "when and why" of scientific maturity indices without an inquiry-based pedagogical structure (E-Agri, n.d.).

The post-test results for the control group, which was exposed to Project-Based Learning alone, indicated a positive progression in analytical competence regarding postharvest maturity. Out of the 37 participants, 4 students (10.81%) achieved a score of 6–7, 19 students (51.35%) achieved a score of 4–5, 14 students (37.84%) achieved a score of 2–3, and 0 student (0.00%) achieved a score of 0–1.

These results classified the students into the Excellent, Proficient, Developing, and Beginning categories, respectively. While the standard Project-Based Learning curriculum helped more than half of the class improve, a significant portion still struggled to consistently apply complex maturity indices. The persistent "Developing" segment and the relatively low "Excellent" rate were consistent with Cognitive Load Theory; as Sweller (1988) and Hendrayana et al. (2020) suggest, students in unstructured environments may experience cognitive overload that prevents high-tier mastery. This supports the argument by Kirschner et al. (2006) that minimally guided instruction can be less effective for complex tasks because it fails to provide the specific mental schemas needed to differentiate between variables like subtle shifts in maturity indices. Ultimately, this suggested that while PBL alone was effective for general improvement, it lacked the instructional scaffolding necessary to move the entire cohort into a higher level of analytical mastery.

Table 2

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning Alone in terms of Problem-Solving

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	3	8.11	4	10.81	Excellent
4 – 5	9	24.32	13	35.14	Proficient
2 – 3	20	54.05	18	48.65	Developing
0 – 1	5	13.51	2	5.40	Beginning
Total	37	100.0	37	100.0	

The pre-test scores for the control group regarding their problem-solving competence indicated that a majority of the students possessed a baseline understanding of postharvest issues but struggled with advanced technical application. Out of the 37 participants, 3 students (8.11%) achieved a score of 6–7, 9 students (24.32%) achieved a score of 4–5, 20 students (54.05%) achieved a score of 2–3, and 5 students (13.51%) achieved a score of 0–1.

These results classified the students into the Excellent, Proficient, Developing, and Beginning categories, respectively. This suggested that the bulk of the class was in the early stages of learning how to apply the TLC (Tender, Loving, Care) principles to real-world agricultural problems, such as managing field heat or preventing tissue ruptures. This distribution aligned with findings by Law et al. (2020), who suggested that "ill-structured" problems required a level of cognitive flexibility that most students had not yet developed through traditional rote instruction. The prevalence of students in the lower categories underscored the necessity of moving beyond simple Project-Based Learning toward more structured inquiry models, as students in standard project environments often remained at a superficial level of problem-solving without explicit guidance in reasoning (Sánchez-García & Reyes-de-Cózar, 2025). This initial state confirmed that the control group provided a valid baseline to measure the comparative efficacy of the experimental intervention.

The post-test scores for the control group regarding their problem-solving competence indicated that while some students improved through Project-Based Learning alone, a near majority remained at the foundational levels of application. Out of the 37 participants, 4 students (10.81%) achieved a score of 6–7, 13 students (35.14%) achieved a score of 4–5, 18 students (48.65%) achieved a score of 2–3, and 2 students (5.40%) achieved a score of 0–1.

These results classified the students into the Excellent, Proficient, Developing, and Beginning categories, respectively. This outcome was consistent with Cognitive Load Theory, which suggests that when students engage in unstructured tasks without specific guidance, their working memory can be overwhelmed by the complexity of the problem space, hindering the development of high-level mental models (Chen et al., 2023). While the standard curriculum provided some growth, the high percentage of students in the Developing category—nearly half of the class—suggested that many were still operating at a rote or intuitive level rather than achieving "meaningful" problem-solving (Main, 2023). These students demonstrated a strengthened ability to diagnose causes of decay compared to the pre-test, yet they continued to face challenges in consistently applying TLC (Tender, Loving, Care) principles to resolve postharvest issues. This indicated that while PBL alone facilitated a decrease in the Beginning population, it did not fully bridge the gap for a significant portion of the cohort.

Table 3

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning Alone in terms of Decision-Making

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0.0	1	2.71	Excellent
4 – 5	16	43.24	12	32.43	Proficient
2 – 3	16	43.24	16	43.24	Developing
0 – 1	5	13.51	8	21.62	Beginning
Total	37	100.0	37	100.0	

The pre-test scores for the control group regarding their decision-making skills indicated a fairly even split between the intermediate proficiency levels. Out of the 37 participants, 0 student (0.00%) achieved a score of 6–7, 16 students (43.24%) achieved a score of 4–5, 16 students (43.24%) achieved a score of 2–3, and 5 students (13.51%) achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This distribution suggested that while a significant portion of the class could identify some superior damage-reduction strategies, an equal number still struggled to consistently prioritize biological integrity over logistical convenience in scenarios involving packing and transport. The data further showed that the 13.51% of students at the Beginning level possessed a minimal understanding of how to reduce mechanical injury. Notably, the total absence of students in the Excellent category confirmed that high-tier mastery was not present at the onset of the study, aligning with baseline trends in the experimental group.

This concentration in the mid-to-lower tiers aligned with Rational Choice Theory, which suggests that without specific training, individuals often operate under bounded rationality—choosing the convenient path over the scientifically sound one (Sánchez-García & Reyes-de-Cózar, 2025). As Kitinoja and Kader (2015) noted, decision-making in horticultural supply chains is often compromised when students do not yet understand the "invisible" biological consequences of rough handling and poor climate control.

The post-test scores for the control group in the domain of decision-making indicated that while a segment of the class progressed, a significant majority still struggled to achieve high-level proficiency through Project-Based Learning alone. Out of the 37 participants, 1 student (2.71%) achieved a score of 6–7, 12 students (32.43%) achieved a score of 4–5, 16 students (43.24%) achieved a score of 2–3, and 8 students

(21.62%) achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This distribution suggested that for nearly half of the cohort, the standard curriculum did not sufficiently shift their judgment toward effective damage-reduction strategies, such as optimizing container fit or prioritizing static compression prevention over logistics speed. A concerning trend showed that the number of students at the Beginning level actually increased compared to the pre-test, suggesting that without a structured reasoning framework, some students might have become overwhelmed by the complexities of postharvest decision-making. As Belton and Dhami (2020) noted, rational decision-making is a distinct cognitive ability that requires "de-biasing" strategies. The increase in the Beginning population suggests that without a strategy like CER to act as a "cognitive anchor," students may become confused by the myriad of distractors in advanced horticultural scenarios. Ultimately, as Kitinoja and Kader (2015) emphasized, postharvest loss is largely a result of poor human decision-making, and the data suggests PBL alone is insufficient for developing the critical judgment necessary to prevent mechanical injury and physiological stress.

Table 4

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning Alone in terms of Overall Critical Thinking

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0.0	0	0.0	Excellent
4 – 5	16	43.24	23	62.16	Proficient
2 – 3	21	56.76	14	37.84	Developing
0 – 1	0	0.0	0	0.0	Beginning
Total	37	100.0	37	100.0	

The overall pre-test scores for the control group regarding their critical thinking skills indicated a class that was relatively balanced between the basic and intermediate levels of postharvest knowledge. Out of the 37 participants, 0 student (0.00%) achieved a score of 15–18, 16 students (43.24%) achieved a score of 10–14, 21 students (56.76%) achieved a score of 5–9, and 0 student (0.00%) achieved a score of 0–4.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This suggested that over half of the cohort began the study with only a foundational ability to integrate the concepts of analysis, problem-solving, and decision-making when faced with practical agricultural scenarios. The fact that 100% of the students fell into the middle two tiers indicated a "homogeneity of reasoning" often found in traditional classrooms where instruction focuses on standardized procedures (Facione, 2015). As Zhao et al. (2026) observed in agricultural education, students frequently fail to reach Excellent status because they are not challenged to defend their claims with specific biological evidence. This baseline reinforced the study's premise that without a structured intervention like the Claim-Evidence-Reasoning (CER) model, students are likely to remain within these intermediate boundaries, showing only marginal growth in their ability to handle high-level agricultural dilemmas.

The overall post-test results for the control group regarding their critical thinking skills indicated a general upward trend toward intermediate proficiency, though high-tier mastery remained elusive through Project-Based Learning alone. Out of the 37 participants, 0 student (0.00%) achieved a score of 15–18, 23 students (62.16%) achieved a score of 10–14, 14 students (37.84%) achieved a score of 5–9, and 0 student

(0.00%) achieved a score of 0–4.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This represented a notable improvement from the pre-test phase, suggesting that the standard curriculum successfully moved many students into a more consistent level of technical reasoning. However, the fact that over one-third of the class remained at the Developing level indicated a continued struggle with the integrated application of analysis, problem-solving, and decision-making. Furthermore, the total absence of students in the Excellent category highlighted a plateau in critical thinking growth. According to Paul and Elder (2019), critical thinking requires intellectual standards like precision and logic, which are rarely developed through mere exposure to content. The 37.84% of students remaining in the Developing category highlighted a lack of "critical thinking disposition," or the consistent habit of applying analytical tools to new problems (Facione, 2015). As Williams et al. (2026) observed, the jump from Proficient to Excellent necessitates a deliberate pedagogical shift toward student-led argumentation, reinforcing the premise that the CER strategy is the essential link for achieving top-tier mastery.

Table 5

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning with Claim-Evidence-Reasoning (CER) Strategy in terms of Analysis

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	2	5.26	9	23.68	Excellent
4 – 5	9	23.68	18	47.36	Proficient
2 – 3	27	71.05	9	23.68	Developing
0 – 1	0	0.0	2	5.26	Beginning
Total	38	100.0	38	100.0	

The pre-test results for the experimental group—those designated to undergo Project-Based Learning integrated with the Claim-Evidence-Reasoning (CER) strategy—revealed a baseline performance primarily concentrated in the lower proficiency tiers regarding their analytical skills. Out of the 38 participants, 2 students (5.26%) achieved a score of 6–7, 9 individuals (23.68%) achieved a score of 4–5, 27 students (71.05%) achieved a score of 2–3, and 0 student (0.00%) achieved a score of 0–1.

The heavy concentration in the Developing tier indicated that most students entered the study with only a foundational grasp of how to systematically examine physiological and horticultural data to determine the developmental states of various crops (Awasthi, 2023). It was notable that no students fell into the Beginning category, suggesting that while their analytical depth was limited at the start of the intervention, the entire group possessed at least a minimal baseline understanding of maturity indices and horticultural assessment. These findings highlighted that the group had substantial room for growth in higher-order analytical thinking, justifying the introduction of the CER framework to bridge the gap between simple observation and evidence-based reasoning (Wei et al., 2026). These baseline scores served as the primary point of comparison against post-test results to measure the eventual effectiveness of the integrated PBL and CER approach (Clifton & Clifton, 2019).

The post-test results regarding the analytical competence of the experimental group demonstrated a notable shift toward higher proficiency levels following the integration of Project-Based Learning with the

Claim-Evidence-Reasoning (CER) strategy. Out of the 38 participants, 9 students (23.68%) achieved a score of 6–7, 18 students (47.36%) achieved a score of 4–5, 9 students (23.68%) achieved a score of 2–3, and 2 students (5.26%) achieved a score of 0–1.

This distribution indicated a strengthened ability to evaluate maturity indices and draw valid biological conclusions compared to the pre-test phase, with over 71% of the students now concentrated in the top two proficiency brackets. In the context of vocational horticulture, this analytical growth is crucial; Knobloch and Wang (2024) argue that integrating science into agricultural education via models like CER improves both technical competence and real-world problem-solving. The fact that nearly a quarter of the group reached the Excellent level suggests that the intervention helped students overcome common "surface-level" analysis barriers. As noted by Rumfot et al. (2025), combining authentic project-based tasks with structured reflection is the most effective means of moving technical students toward expert-like performance in analytical tasks.

Table 6

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning with Claim-Evidence-Reasoning (CER) Strategy in terms of Problem-Solving

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0	9	23.68	Excellent
4 – 5	10	26.32	18	47.36	Proficient
2 – 3	17	44.74	9	23.68	Developing
0 – 1	11	28.95	2	5.26	Beginning
Total	38	100.0	38	100.0	

The pre-test data regarding the problem-solving competence of the experimental group indicated that a significant portion of the students struggled to apply technical solutions to postharvest issues before the intervention. Out of the 38 participants, 0 student (0.00%) achieved a score of 6–7, 10 students (26.32%) achieved a score of 4–5, 17 students (44.74%) achieved a score of 2–3, and 11 students (28.95%) achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. The data reflected a critical gap in students' ability to use the TLC (Tender, Loving, Care) principles for practical intervention, as nearly half the class lacked the systematic approach required to diagnose and resolve complex physiological challenges like surging respiration or pathogen entry. Furthermore, the total absence of students in the Excellent tier highlighted a widespread deficiency in linking rough handling or poor environmental management to specific biological outcomes. With over 73% of participants scoring at or below the developing level, the need for a more structured reasoning framework was evident. By implementing Project-Based Learning combined with the Claim-Evidence-Reasoning (CER) strategy (Johnson, 2024; Daraman et al., 2025), the study aimed to move these students toward a proficient and excellent command of postharvest problem-solving.

The post-test evaluation of the experimental group’s problem-solving skills indicated a substantial improvement in their ability to apply the TLC (Tender, Loving, Care) principles to mitigate postharvest decay and physiological stress. Out of the 38 participants, 9 students (23.68%) achieved a score of 6–7, 18 students (47.36%) achieved a score of 4–5, 9 students (23.68%) achieved a score of 2–3, and 2 students (5.26%)

achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This reflected a more consistent capability to diagnose issues like field heat or mechanical injury and implement technically sound solutions, such as immediate precooling or tool maintenance. The jump from zero student in the pre-test to nearly 24% in the Excellent category suggested that the CER model provided the "scaffolded" mental models necessary for high-level problem representation. This is consistent with Manaka (2024), who posited that problem-solving in technical domains like horticulture requires students to accurately represent the problem space. Furthermore, the overall trend—showing over 70% of participants moving into the top two brackets—aligns with findings by Al-Mutawah et al. (2022), who noted that knowledge integration frameworks are significantly more effective for teaching complex scientific concepts than traditional instruction.

Table 7

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning with Claim-Evidence-Reasoning (CER) Strategy in terms of Decision-Making

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0	1	2.63	Excellent
4 – 5	10	26.32	19	50.00	Proficient
2 – 3	20	52.36	14	36.84	Developing
0 – 1	8	21.05	4	10.53	Beginning
Total	38	100.0	38	100.0	

The pre-test scores for the experimental group in the domain of decision-making indicated that majority of the students possessed a limited capacity for selecting optimal postharvest strategies prior to the intervention. Out of the 38 participants, 0 student (0.00%) achieved a score of 6–7, 10 students (26.32%) achieved a score of 4–5, 20 students (52.63%) achieved a score of 2–3, and 8 students (21.05%) achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. The distribution suggested that while more than half of the class could recognize basic logistical choices, they likely struggled to prioritize the biological integrity of the produce over more convenient or faster handling methods, as supported by the study of Palumbo et al. (2022). Furthermore, 21.05% of students at the Beginning level appeared to lack the fundamental understanding necessary to make even basic damage-reduction decisions, such as selecting appropriate container capacities. Mirroring results in other competency areas, the total absence of students in the Excellent tier confirmed that high-level, comprehensive decision-making was not yet a mastered skill within this cohort (Morelli et al., 2021). Overall, these baseline figures reinforced the necessity of the quasi-experimental intervention, as the CER framework requires students to justify logistical choices with scientific evidence to bridge the gap toward expert-level judgment (ModelTeaching, 2019).

The post-test results for the experimental group in the domain of decision-making revealed a significant shift toward higher competency levels following the implementation of Project-Based Learning integrated with the Claim-Evidence-Reasoning (CER) strategy. Out of the 38 participants, 1 student (2.63%) achieved a score of 6–7, 19 students (50.00%) achieved a score of 4–5, 14 students (36.84%) achieved a score of 2–3, and 4 students (10.53%) achieved a score of 0–1.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This represented a substantial improvement from the pre-test, indicating that the intervention effectively enhanced the students' ability to prioritize biological integrity and damage reduction over mere logistical convenience. While a portion of the group remained in the Developing and Beginning categories, the decrease in the Beginning population—from over 21% to roughly 10%—suggested that the CER framework provided a more accessible structure for making sound technical decisions in agricultural transport and packing. This improvement is supported by Decision Theory; as Arkes (1991) and Methling et al. (2022) note, effective decision-making requires resisting mental shortcuts. The CER strategy counteracts these heuristics by forcing students to provide "Reasoning" that explicitly links their "Evidence" to their "Claim."

Table 8

Pre-test and Post-test Scores of the Group Exposed to Project-Based Learning with Claim-Evidence-Reasoning (CER) Strategy in terms of Overall Critical Thinking

Scores	Pretest		Posttest		
	Frequency	Percentage	Frequency	Percentage	Description
6 – 7	0	0.0	9	23.68	Excellent
4 – 5	15	39.47	19	50.00	Proficient
2 – 3	21	55.26	10	26.32	Developing
0 – 1	2	5.26	0	0.0	Beginning
Total	38	100.0	38	100.0	

The overall pre-test scores for the experimental group regarding their critical thinking skills indicated that most students began the study with a basic to intermediate grasp of postharvest concepts. Out of the 38 participants, 0 student (0.00%) achieved a score of 15–18, 15 students (39.47%) achieved a score of 10–14, 21 students (55.26%) achieved a score of 5–9, and 2 students (5.26%) achieved a score of 0–4.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. The heavy concentration in the Developing range suggested that while students could identify some correct handling procedures, they likely struggled to consistently connect biological evidence with technical reasoning across the domains of analysis, problem-solving, and decision-making. The total absence of Excellent scores confirmed that none of the participants initially possessed a comprehensive mastery of integrated postharvest principles, a common trend in vocational education where students often memorize procedures without understanding the underlying biological "why" (Pasquinelli & Richard, 2023). Furthermore, this distribution aligned with the findings of Vo et al. (2024), noting that critical thinking requires structured "scaffolding" to transition from simple identification to complex evaluation. These results validated the implementation of the Claim-Evidence-Reasoning (CER) model to help students develop the rigorous mental habits needed to navigate advanced postharvest management.

The overall post-test results for the experimental group in the domain of critical thinking reflected a significant and positive shift in student performance following the implementation of Project-Based Learning combined with the Claim-Evidence-Reasoning (CER) strategy. Out of the 38 participants, 9 students (23.68%) achieved a score of 15–18, 19 students (50.00%) achieved a score of 10–14, 10 students (26.32%) achieved a score of 5–9, and 0 student (0.00%) achieved a score of 0–4.

These results classified the participants into the Excellent, Proficient, Developing, and Beginning categories, respectively. This marked a notable increase from the pre-test and indicated that a majority of the cohort developed a reliable ability to navigate complex horticultural scenarios by selecting the best possible answers over plausible distractors. The significant gains in performance were consistent with Bloom's Taxonomy (Revised), which highlights the cognitive shift from "Remembering" to "Analyzing" and "Evaluating" (Stanton et al., 2021). The jump to the Excellent tier indicated that students successfully integrated the sub-domains of analysis and problem-solving into a holistic evaluation process, a hallmark of advanced critical thinking. Furthermore, by requiring students to link a claim to specific horticultural evidence, the intervention effectively suppressed impulsive thinking, supporting the findings of Paul and Elder (2019) and Khishfe (2020) that explicit instruction in argumentative structures significantly improves performance in science-based dilemmas.

The Significant Difference between the Pre-test and the Post-test Scores of the Group Exposed to Project-Based Learning Alone

Table 9

Significant Difference between the Pre-test and the Post-test Scores of the Group Exposed to Project-Based Learning Alone

Variables	Pretest		Posttest		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Analysis	2.89	1.20	3.86	1.36	-3.898	36	.000
Problem Solving	3.16	1.50	3.46	1.64	-1.281	36	.208
Decision Making	3.11	1.26	2.89	1.37	1.052	36	.300
Critical Thinking	9.16	2.56	10.22	3.20	-6.812	36	.000

Legend: $p<.05$ – significant; $p>.05$ – not significant

The statistical analysis for the control group revealed a mixed performance outcome when utilizing Project-Based Learning (PBL) alone. While there was a significant improvement in the categories of Analysis and overall Critical Thinking, the results for Problem Solving and Decision Making failed to reach statistical significance. Specifically, the Analysis mean rose from 2.89 to 3.86 with a p-value of .000, and the overall Critical Thinking mean increased from 9.16 to 10.22, also with a p-value of .000. These specific results allowed for the rejection of the null hypothesis in those domains, indicating that the traditional project-based approach did indeed foster basic analytical growth and general subject-matter awareness.

However, the results failed to reject the null hypothesis for the domains of Problem Solving and

Decision Making. In Problem Solving, the mean score saw only a marginal increase from 3.16 to 3.46, resulting in a p-value of .208. Even more notably, the Decision-Making mean actually decreased from 3.11 to 2.89 with a p-value of .300. These figures suggested that without a structured reasoning framework, students in the control group were unable to make significant gains in their ability to resolve technical postharvest issues or make sound logistical judgments.

Therefore, the decision to classify the hypothesis as rejected is grounded in the divergent statistical outcomes observed between the two study groups across the various competency domains. While the null hypothesis was completely rejected for the experimental group which demonstrated significant growth in Analysis, Problem Solving, Decision Making, and overall Critical Thinking ($p < .05$) the results for the control group were inconsistent. Specifically, the control group showed significant improvement only in Analysis and Critical Thinking, while failing to achieve a statistically significant difference in the critical areas of Problem Solving ($p = .208$) and Decision Making ($p = .300$)

In summary, the data indicated that while traditional Project-Based Learning was effective for improving basic analytical competency, it was insufficient for developing the more complex, evidence-based skills required for high-level problem-solving and decision-making. The lack of a significant difference in these key areas underscored a plateau in student development. This suggested that while students gained a general understanding of the material, they struggled to translate that knowledge into consistent, technically sound professional judgment when faced with the multifaceted challenges of agricultural logistics.

The Significant Difference between the Pre-test and the Post-test Scores of the Group Exposed to Project-Based Learning Combined with Claim-Evidence-Reasoning (CER) Strategy

Table 10

Significant Difference between the Pre-test and the Post-test Scores of the Group Exposed to Project-Based Learning Combined with Claim-Evidence-Reasoning (CER) Strategy

Variables	Pretest		Posttest		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Analysis	3.13	1.04	4.32	1.44	-5.244	37	.000
Problem Solving	2.50	1.47	4.32	1.58	-6.888	37	.000
Decision Making	2.61	1.20	3.42	1.39	-3.266	37	.002
Critical Thinking	8.24	2.54	12.05	3.47	-20.293	37	.000

Legend: p<.05 – significant; p>.05 – not significant

The statistical analysis indicates a highly significant improvement in student performance following the implementation of Project-Based Learning combined with the Claim-Evidence-Reasoning (CER) strategy. Across all assessed variables—Analysis, Problem Solving, Decision Making, and the overall Critical Thinking score—the mean scores increased notably from the pre-test to the post-test. Specifically, the total critical thinking mean rose from 8.24 to 12.05, and the associated p-value of .000 was far below the standard .05 alpha level. This demonstrated that the growth in student competency was not due to random chance but was a direct result of the pedagogical intervention.

Consequently, the null hypothesis was rejected. The t-values for each category, such as −20.293 for overall critical thinking and −6.888 for problem solving, confirmed a strong and statistically significant shift in the students' academic abilities. This suggested that the structured CER framework effectively bridged the gaps in student reasoning, allowing them to move from basic identification to more complex application of postharvest principles.

The improvement in the decision-making domain, while having a slightly higher p-value of .002 compared to the other variables, still remained statistically significant. This indicated that the integrated strategy successfully enhanced the students' professional judgment and their ability to justify technical choices with scientific evidence. Overall, the data consistently showed that the combination of hands-on projects with formal argumentative scaffolding led to a meaningful and measurable increase in higher-order thinking skills within the experimental group.

The results strongly highlight the benefits of combining Project-Based Learning (PBL) with the Claim-Evidence-Reasoning (CER) approach, especially when it comes to enhancing students' problem-solving and decision-making skills—areas in which PBL by itself proved inadequate. The use of CER challenges students to participate in a more rigorous cognitive process, in contrast to standard PBL, which frequently places an emphasis on task completion and product creation. In addition to being encouraged to investigate ideas through study and observation, learners are methodically assisted in analyzing the information they have obtained and developing solid arguments to back up their arguments. Because students must defend their choices with reasoned, fact-based arguments rather than depending solely on instincts or shallow knowledge, this methodical approach fosters deeper intellectual engagement. They consequently gain the capacity to assess various options critically, foresee outcomes, and make well-informed decisions based on technical expertise. The experimental group's notable gains in problem-solving and decision-making indicate that CER successfully fills in the gaps in traditional PBL, turning it from a largely experiential activity into a cognitively demanding process that promotes higher-order thinking and disciplined reasoning necessary for challenging, real-world applications.

The Significant Difference in the Post-test Scores between the Group Exposed to Project-Based Learning Combined with Claim-Evidence-Reasoning (CER) Strategy and the Group Exposed to Project-Based Learning Alone

Table 11

Significant Difference between the Post-test Scores of the Group Exposed to Project-Based Learning Combined with Claim-Evidence Reasoning Strategy and the Group Exposed Project-Based Learning Alone

Variables	PBL Alone		PBL with CER		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Strategies	10.22	3.20	12.05	3.47	2.381	73	.020

Legend: p<.05 – significant; p>.05 – not significant

The statistical analysis revealed a significant difference between the post-test scores of the two groups, favorably supporting the integration of the Claim-Evidence-Reasoning (CER) strategy. The experimental group, which utilized Project-Based Learning (PBL) combined with CER, achieved a higher mean score of 12.05 compared to the 10.22 mean score of the control group that used Project-Based Learning alone. With a calculated t-value of 2.381 and a p-value of .020, the results fell below the standard .05 significance threshold. This indicated that the performance gap between the two groups was statistically meaningful and likely a result of the specific instructional intervention rather than random variation.

The group that was exposed to Project-Based Learning (PBL) using the Claim-Evidence-Reasoning (CER) framework performed better on the post-test because of both the structured nature of CER and the additional dimension of meaningful student interaction that developed naturally during its implementation. PBL + CER required students to actively propose, defend, and critically assess ideas through evidence-based debates, in contrast to PBL alone, where collaboration is frequently restricted to task completion and product development. During presentations, students had to explain their ideas, provide evidence to support them, and develop logical arguments. This prompted queries, rebuttals, and peer assessment. This process extended learning beyond the production stage into increased cognitive involvement by promoting lively, student-driven argumentative conversations. As a result, students were engaging in what can be considered a developing component—"Interaction"—in addition to carrying out CER as a procedural requirement, which greatly aided in refining their analytical, problem-solving, and decision-making skills. Through these discussions, students were exposed to different points of view, encouraged to reconsider their conclusions, and prompted to defend their reasoning, all of which improved their higher-order thinking skills. In the end, this dynamic and conversational environment gave the experimental group a distinct advantage over the simpler and less mentally challenging PBL framework alone since it promoted a more comprehensive and lively learning experience.

Based on these findings, the null hypothesis was rejected. The data suggested that while Project-Based Learning was an effective teaching method on its own, its impact was significantly amplified when paired with the CER framework. The structured requirement for students to justify their claims with evidence and scientific reasoning appeared to provide a superior cognitive advantage, leading to higher-tier mastery of the subject matter compared to traditional project-based methods.

This significant difference underscored the value of using argumentative scaffolding to enhance critical thinking skills in technical subjects. By forcing a more deliberate connection between theoretical concepts and practical applications, the CER-integrated approach successfully pushed students toward a deeper level of competency. Consequently, the results provided strong evidence that the combined strategy was a more effective pedagogical tool for improving student outcomes in complex agricultural scenarios than utilizing project-based learning in isolation.

4. Conclusion and Recommendations

Based on the statistical analysis and the comparison of performance data between the experimental and control groups, the following conclusions were drawn:

- The integration of Project-Based Learning combined with the Claim-Evidence-Reasoning (CER) strategy significantly improved students' performance across all domains, as shown by the increase in mean scores and p-values below .05. Therefore, the hypothesis stating there is no significant difference between the pre-test and the post-test scores of the group exposed to Project-Based Learning combined with Claim-Evidence-Reasoning (CER) strategy is REJECTED.

- The group exposed in Project-Based Learning exclusively demonstrated notable enhancements in Analysis and total Critical. Nonetheless, no notable enhancement was detected in Problem Solving and Decision Making. Consequently, the hypothesis stating that there is no significant difference between the pre-test and the post-test scores of the group exposed to Project-Based Learning alone is REJECTED.
- A significant difference was found between the post-test scores of the two groups, with the experimental group obtaining a higher mean score than the control group, supported by a computed p-value of .020. Therefore, the hypothesis stating that there is no significant difference between the post-test scores of each group exposed to Project-Based Learning combined with Claim-Evidence-Reasoning (CER) strategy and the group exposed to Project-Based Learning alone is REJECTED.

Based on the findings and conclusions of this research, the following recommendations are proposed for educators, administrators, and future researchers:

- It is highly recommended that instructors in agricultural and vocational education may integrate the Claim-Evidence-Reasoning (CER) framework into their standard Project-Based Learning (PBL) activities. Since the study proved that hands-on projects alone may lead to a proficiency plateau, adding a formal requirement for students to justify their technical choices with scientific evidence will ensure they move beyond rote memorization toward high-level professional judgment.
- Educational institutions may provide targeted training and workshops for faculty members on how to scaffold argumentative reasoning within technical subjects. Educators need to be equipped with the tools to transition from being "providers of facts" to "facilitators of inquiry," specifically focusing on helping students identify biological maturity indices and mitigate postharvest stress through evidence-based claims.
- School administrators and curriculum developers may consider redesigning course modules to include explicit "thinking protocols." Rather than focusing solely on the successful completion of a project (e.g., harvesting or packing), assessment rubrics should weigh heavily on the student's ability to analyze problems and defend their decisions. This shift will help eliminate the "Beginning" proficiency category and push more students into the "Excellent" tier.
- Given the significant gap in decision-making and problem-solving within the control group, it is recommended that instructional materials for agricultural logistics include visual and structural scaffolds. Using CER templates during practical simulations of transport and packing can act as a cognitive anchor, preventing students from making convenience-based decisions that compromise the biological integrity of the produce.
- Further research may be conducted to test the longitudinal effects of the CER-integrated PBL approach. Future studies could investigate whether these critical thinking gains are sustained when students enter the professional workforce or if the strategy is equally effective in other technical domains such as Fisheries, Animal Science, or Agricultural Engineering. Additionally, expanding the study to a larger, more diverse demographic would help validate the generalizability of these findings across different educational settings.

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