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Effectiveness of Claim-Evidence-Reasoning (CER) Framework in Students' Understanding of Projectile Motion

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Abstract: The study investigates the effectiveness of the Claim-Evidence-Reasoning (CER) Framework in enhancing students' understanding of projectile motion. Many students struggle with conceptualizing the projectile motion due to its abstract nature, necessitating innovative instructional strategies. This study aims to determine whether the CER framework improves students' comprehension of projectile motion concepts. A quasi-experimental design was employed which utilizes a two-group pretest-posttest setup, with one group exposed to the CER framework and the other receiving traditional instruction. The study was conducted among Grade 12 STEM students at Emilio Aguinaldo College-Manila, with data collected through adapted science process skills assessments and thematic analysis of student perceptions. Results indicated that students who were taught using the CER framework demonstrated significantly higher post- test scores compared to those in the traditional teaching group. Qualitative findings further revealed that students perceived the CER framework as beneficial in breaking down complex problems and deepens their critical thinking and conceptual understanding. The study concludes that the CER framework is an effective instructional strategy for improving students' grasp of projectile motion. It is recommended that educators incorporate CER-based exercises, guided practice sessions, and visual aids to enhance its implementation. Future research could explore its applicability in other physics topics and across different student demographics.

Keywords: Claim-Evidence-Reasoning Framework, Critical Thinking, Physics Education, Projectile Motion, Teaching Strategies

I. INTRODUCTION

Educators have continuously explored and discovered teaching strategies to enhance students' understanding of scientific concepts. The Claim-Evidence-Reasoning (CER) framework is one such strategy that aims to develop critical thinking by guiding students to construct logical evidence-based explanations. While the CER framework has been studied in various science disciplines, its application to learning projectile motion in physics remains unexplored.

Projectile motion is a fundamental yet challenging topic in physics, as students often develop misconceptions about how objects move in two-dimensional space under the influence of gravity. Traditional teaching methods, including lectures and demonstrations, have shown limited success in addressing these misconceptions. Thus, there is a need for innovative, research-based instructional strategies to improve students conceptual understanding of projectile motion.

This study seeks to fill this gap by examining how the CER framework impacts students' comprehension of projectile motion. By encouraging students to break down problems into claims, support them with evidence, and justify their reasoning, CER will provide a more structured and interactive learning approach compared to conventional methods. The findings of this study will contribute to the growing body of research on scientific reasoning and physics education, which will provide data into the potential of CER as an effective tool for teaching motion-related concepts.

II. METHODOLOGY

2.1. Methods

This study employed a quasi-experimental research design using a two-group, pretest-posttest setup to evaluate the effectiveness of Claim-Evidence-Reasoning (CER) framework in students' understanding of projectile motion. The study compared an experimental group (CERPROJ) which was exposed to CER framework, and a control group (CPROJ) which received conventional instruction.

2.2. Participants

The study was conducted at Emilio Aguinaldo College-Manila, Senior High School Department, during the second quarter of the academic year 2023-2024. The participants were grade 12 STEM students taking general physics 1, as projectile motion is covered in their curriculum. A purposive sampling technique was used based on students' enrollment in their course. The participants were then divided into two groups as both groups had similar academic backgrounds in physics before the intervention.

2.3. Instruments

To assess students' understanding of projectile motion, a validated questionnaire adapted from Jeenthong's science process skills was used. The instrument included conceptual and problem-solving questions related to projectile motion and was designed to

measure critical thinking and application skills. The questionnaire had a Cronbach's alpha reliability coefficient of 0.892 which indicates high internal consistency. Additionally, structured surveys and open-ended questionnaires were administered to gather qualitative data on students' perception of CER framework.

2.4. Data Collection Procedure

The study was conducted in three phases. The pre-implementation phase involved securing permission from school administrators, obtaining informed consent from students and guardians, and administering a pretest to both groups to establish their baseline understanding of projectile motion. The implementation phase involved different teaching methods for the two groups. The control group (CPROJ) received traditional instruction through teacher-led lectures, demonstrations, and problem-solving activities, while the experimental group (CERPROJ) was taught using the CER framework. Students in the CERPROJ group were required to formulate a claim about a projectile motion scenario, provide evidence based on problem- solving or experimental data, and justify their reasoning using physics principles. Both groups participated in problem-solving exercises, but only the CERPROJ group explicitly followed the CER model in their explanations and discussions. The post-implementation phase involved administering a posttest identical to the pretest to measure learning gains. Additionally, students in the experimental group completed structured surveys and open-ended questionnaires to assess their perceptions of the CER framework.

2.5. Data Analysis

The study used quantitative and qualitative methods. Independent samples t-tests were conducted to compare pretest and posttest scores between the control and experimental groups, determining whether the CER framework led to statistically significant improvements in learning. Paired t-tests were used to assess within-group differences, analyzing the progress of each group from pretest to posttest. Thematic analysis was applied to responses from open-ended questionnaires to identify recurring themes related to students' experiences, benefits, and challenges in using the CER framework.

III. RESULTS AND DISCUSSION

3.1. Effectiveness of CER in enhancing students' understanding of Projectile Motion

The pretest results indicate that students in the CERPROJ group (CER framework) had slightly higher initial scores than those in the CPROJ group (traditional instruction), though the difference was not statistically significant. However, posttest results revealed that students in the CERPROJ group significantly outperformed those in the CPROJ group. The mean posttest score for CERPROJ was higher than that of the CPROJ group, suggesting that the CER framework effectively improved conceptual understanding. Statistical analysis using an independent samples t-test confirmed a significant difference in learning gains between the two groups, indicating that the CER approach led to greater improvement in students' ability to analyze and apply projectile motion concepts.

3.2. Independent Samples t-Test: CERPROJ vs. CPROJ

An independent samples t-test was conducted to compare the posttest scores of the CERPROJ (CER framework) and CPROJ (traditional instruction) groups. The results showed a statistically significant difference between the two groups ($p < 0.001$), indicating that students taught using the CER framework demonstrated significantly greater improvements in understanding projectile motion compared to those taught through conventional methods.

Table 1

Independent Samples t-Test Results for CERPROJ and CPROJ Posttest Scores

Group	*M*	*SD*	*t*-value	*p*-value	Interpretation
CERPROJ (CER Framework)	26.37	3.12	4.76	< .001	Significant Difference
CPROJ (Traditional)	21.76	4.37	2.93	.004	Significant Difference

Note. *M* = Mean; *SD* = Standard Deviation; $p < .05$ considered statistically significant.

These findings confirm that the CER framework is a more effective instructional strategy than traditional lecture-based teaching in improving students' conceptual grasp of projectile motion.

3.3. Paired t-Test: Pretest and Posttest Comparisons

A paired t-test was used to compare the pretest and posttest scores within each group to assess learning gains. The CERPROJ group showed a significantly larger mean increase, reinforcing the effectiveness of CER-based instruction.

Table 2

Paired t-Test Results for Pretest and Posttest Scores Within Groups

Group	Pretest *M* (SD)	Posttest *M* (SD)	Mean Increase	*t*-value	*p*-value	Interpretation
CERPROJ (CER Framework)	19.85 (3.45)	26.37 (3.12)	+6.52	7.65	< .001	Significant Improvement
CPROJ (Traditional)	19.43 (4.21)	21.76 (4.37)	+2.33	6.13	< .001	Significant Improvement

Note. *M* = Mean; *SD* = Standard Deviation; $p < .05$ considered statistically significant.

The results indicate that while both instructional approaches led to improvement, CER resulted in a significantly greater learning gain compared to traditional methods.

3.4. Students' Perceptions of the CER Framework

To further analyze the impact of the CER framework, students' feedback was categorized into themes based on their experiences, challenges, and perceived benefits of using CER in learning projectile motion.

Students expressed positive experiences with CER, reporting that it helped simplify problem-solving, encouraged logical reasoning, and deepened their conceptual understanding.

Table 3

Thematic Analysis of Students' Perceptions of the CER Framework

Theme	Sub-theme	Responses
Breaking down complexity	Helps in structuring problem-solving	"The CER strategy helped me break down the problem into smaller parts, making it easier to understand the trajectory."
Critical thinking development	Moves beyond memorization to analytical thinking	"The CER method forced me to think critically about the principles of projectile motion, rather than just memorizing formulas."
Deeper conceptual understanding	Improved reasoning and connections between concepts	"Explaining my reasoning helped me understand the concepts at a deeper level."
Application of knowledge	Practical understanding of motion principles	"CER made me see the importance of air resistance in projectile motion, which I never noticed before."

Note. Themes were identified from students' qualitative feedback on their experience using the CER framework.

These findings suggest that students perceived CER as an effective tool that not only improved their problem-solving skills but also deepened their understanding of motion concepts.

IV. CONCLUSION AND RECOMMENDATIONS

The findings of this study indicate that the Claim-Evidence-Reasoning (CER) framework is an effective instructional approach for improving students' understanding of projectile motion, as evidenced by the greater learning gains observed in the experimental

group. It is recommended that educators integrate guided CER exercises, provide structured support for constructing explanations, and incorporate real-world applications to further enhance students' engagement and learning outcomes in physics. Future research may explore the long-term effects of CER on student performance across different scientific concepts and educational settings.

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