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Exploring the Use of Claim-Evidence-Reasoning in Promoting Scientific Reasoning Skills of Elementary School Students

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While previous research has shown that claim-evidence-reasoning can effectively promote higher-order thinking skills in science education, more research should be done on using claim-evidence-reasoning in elementary school settings. This study aims to investigate the effectiveness of claim-evidence-reasoning in promoting the scientific reasoning skills of elementary school students. The study utilized a convergent mixed-methods quasi-experimental design, incorporating both quantitative and qualitative data. The participants were 29 Grade 5 students. The discussion lasted for 12 meetings. The quantitative data were collected through a pre-test and post-test, which measured the students' performance in claim, evidence, and reasoning categories. The qualitative data were gathered through open-ended questions that asked the students about their experiences. The results showed a marked improvement in all three categories of claim, evidence, and reasoning in the post-test compared to the pre-test. The number of students scoring 0 points in each category decreased significantly, while the number of students scoring 2 points in each category increased. The post-test mean (M=4.31) was significantly higher than the pre-test mean (M=2.34). Furthermore, the qualitative data supported the quantitative findings, indicating that the claim-evidence-reasoning framework helped students connect the learning materials and concepts they learned in class and organize their thoughts before writing their explanations.

Keywords: cer framework, claim-evidence-reasoning, argumentation skills, scientific reasoning

INTRODUCTION

Science educators have long recognized the need for students to engage productively in scientific argumentation. However, this can be challenging for many students, as the ability to construct and communicate knowledge, use a conceptual framework, and provide evidence for claims requires specific skills (Faize, Husain, & Nisar, 2017). To address this issue, the first author of this study collaborated with colleagues in the research field to develop and implement novel instructional strategies and assessment tools to improve students' proficiency in constructing and evaluating scientific arguments, utilizing the Claim, Evidence, and Reasoning (CER) Framework.

The CER framework teaches students to construct an argument using a claim, evidence, and reasoning (McNeill, Lizotte, Krajcik, and Marx, 2006), which has demonstrated its effectiveness in promoting scientific reasoning skills across various science topics and educational levels, such as biology in high school (Llewellyn & Ullock, 2017; Nageotte et al., 2018; Wallon et al., 2018), earth science in junior high school (Short et al., 2020), and chemistry in undergraduate course (Atkinson et al., 2020).

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Scientific reasoning skill is part of higher-order thinking skill, which is at the top level of thinking ability in Revised Bloom's Taxonomy (Yanto & Subali, 2019).

The CER framework has also demonstrated its compatibility in various aspects of education. Some studies have incorporated CER into different teaching approaches, such as inquiry-based learning (Llewellyn & Ullock, 2017; Kennedy & Folkes, 2018; Nageotte, N., Buck, G., & Kirk, H., 2018, Antonio & Prudente, 2021), game-based approach (Wallon, Jasti, C., Lauren, H. Z. G., & Hug, B., 2018), CER framework along with fading scaffolds (Masters & Docktor, J., 2022) to improve students' argumentation skills and content knowledge, and while other studies have integrated it as part of their assessment design (Atkinson, M.B., Krishnan, S., McNeil, L. A., Luft, J. A., & Pienta, N. J., 2020; Short, Van der Eb, M. Y., & McKay, S. R., 2020).

In this study, the authors sought to build upon this existing research by investigating the effectiveness of a CER-based instructional intervention in promoting scientific argumentation skills among students in a specific educational setting. By doing so, they aimed to contribute to the broader understanding of effective science education practices and equip students with the skills necessary to communicate their scientific understanding effectively.

Literature Review

Academic literacy depends on argumentation, establishing claims, and utilizing evidence to support those assertions (Su et al., 2021). Argumentation in science education is a logical and rational discourse to find relationships between ideas and evidence that involves developing, evaluating, and validating scientific knowledge and constructing the knowledge described (Faize et al., 2017). Students require specific abilities, such as understanding and using a conceptual framework, using correct epistemology for evaluating a claim, and constructing and communicating knowledge as a social interaction process to engage productively in scientific argumentation (Faize et al., 2017).

Researchers investigated different frameworks to improve students' argumentation skills. The structured, guided, and free inquiry can significantly improve students' argumentation skills compared to the conventional method (Yanto, et al., 2019). Another framework is the Claim-Evidence-Reason (CER), widely used in science education to enhance students' argumentation skills and promote critical thinking and scientific literacy (McNeill & Krajcik, 2011). According to this framework, students are taught to construct an argument that includes a claim, evidence, and a reasoning component (McNeill et al., 2006). The claim refers to the statement being made, while the evidence is the data or information used to support the claim. The reasoning component connects the claim and evidence and explains how the evidence supports the claim (McNeill et al., 2006).

Several studies have demonstrated the effectiveness of incorporating the claim-evidence-reasoning (CER) framework in teaching scientific argumentation skills and promoting student conceptual learning. For instance, Llewellyn and Ullock (2017) designed a lesson plan that involved researching the thermoregulation of dinosaurs and using evidence-based reasoning to support claims, which proved effective in promoting scientific argumentation in biology. Kennedy and Folkes (2018) showed that an anchor activity using the CER framework led to significant improvement in the ability of middle school students to write effective scientific arguments. In the study of Wallon et al. (2018), a game-based approach using the CER framework in a high school biology class resulted in higher student argument scores. Moreover, Antonio & Prudente (2021) innovatively integrated CER with metacognitive argument-driven inquiry, proving highly effective in aiding students' comprehension of the biology lesson on antimicrobial resistance while simultaneously honing their argumentation skills. Additionally, Masters and Docktor (2022) suggested that the CER framework, along with fading scaffolds, can be effective in helping preservice teachers learn how to construct a scientific explanation.

Incorporating the CER framework in assessment tools has also effectively promoted student learning. For example, Atkinson et al. (2020) found that engaging students in activities using the CER framework led to a greater understanding of chemistry content in a preparatory chemistry course. Short et al. (2020) investigated using CER in an assessment design, where teachers used it to provide feedback to students and encourage them to reflect on their learning progress.

According to previous studies, CER activities are effective in promoting scientific reasoning skills in various science topics, such as biology in high school (Llewellyn & Ullock, 2017; Nageotte et al., 2018; Wallon et al., 2018; Antonio & Prudente, 2021), earth science in junior high school (Short et al. 2020), and chemistry in undergraduate course (Atkinson et al., 2020).

However, it is essential to note that implementing the CER framework in the classroom may require explicit instruction and support from the teacher, as well as analysis of classroom implementation (Wallon et al., 2018). Providing a suitable and stimulating learning environment, clear instructions, and information about the structure/components of argumentation, encouraging thinking, and asking questions are essential factors in involving students in argumentation (Faize et al., 2017).

In a study by Nageotte et al. (2018), students were given a worksheet with guiding questions to help them construct their claims, evidence, and reasoning. Despite the teacher's emphasis on the importance of evidence, students struggled to apply scientific reasoning and relied on superficial features of the species they were studying. This highlights the need for more targeted support to help students select relevant information and use evidence effectively.

Kennedy and Folkes (2018) found that teaching students to write CER statements independently of any science content was insufficient for supporting their understanding of the framework. Instead, scaffolded questions were needed to help students articulate their understanding of the science topic. The authors also suggested that having students practice writing each CER component before moving on to the next one, as well as using key phrases such as "If...the...because…so…", "My evidence shows/suggests/indicates," "This supports my claim by…because…", "Therefore…", and "In conclusion" could be helpful for English language learners and other students struggling to express their ideas clearly.

In this study, the authors sought to build upon this existing research by investigating the effectiveness of a CER-based instructional intervention in promoting scientific argumentation skills among students in a specific educational setting. Specifically, the study aimed to address the following research questions:

1 What are the effects of CER activities on elementary school students' scientific reasoning skills on phases of the moon and constellations?

2 How do elementary school students perceive CER activities on phases of the moon and constellations in terms of usefulness?

By doing so, this study aimed to contribute to the broader understanding of effective science education practices and equip students with the skills necessary to effectively communicate their scientific understanding.

METHOD

Study design

This study employed mixed methods research to collect data pertinent to the different inquiry facets of the research goal and objectives. Mixed methods research is a research design that involves collecting, analyzing, and integrating quantitative and qualitative data in a single study or a series of studies. It can provide a more comprehensive understanding of research problems using the strengths of quantitative and qualitative research methods (Creswell & Plano Clark, 2018). The design will include both pre/post-test and open-ended questions. The pre/post-test was used to collect quantitative data on the student’s conceptual understanding of the moon's phases, while the open-ended questions were used to collect qualitative data on the student’s perceptions of the usefulness of CER.

Participants

The participants in this study were 29 grade 5 students belonging to a class in a private school. The participants were between 10 and 12 years old (M = 10.4, SD = 0.53). Most participants were males (59%), while the remaining were females (41%).

Instruments

In this section of the research paper, the instruments used to measure the students' conceptual understanding and argumentation skills will be described in detail. These instruments include the Stars and Constellations Conceptual Test, CER tests, and open-ended questions. The Stars and Constellations Module, a unit plan developed by the teacher-researchers, will also be discussed.

These tests aim to measure the argumentation skills of the students. There are three CER tests: one for the pre/post-test and two for the formative test. The CER tests were subject to evaluation by the department head and other subject teachers. Notably, no revisions or suggestions for improvements were proposed following the review. The students were asked to follow specific guidelines in their argumentation. The first guideline instructed participants to identify and circle the relevant keywords in the question. The second guideline encouraged participants to make a concise statement or argument using the phrase "I observed/noticed/compared... The effect of…". The third guideline required participants to support their claims with evidence from the text, using phrases such as "The data shows…", "The text tells us that…" or "The author explains that...". The fourth guideline encouraged participants to provide reasoning by using phrases like "This is important because…", "This shows that…" or "Therefore..." to connect their evidence to their claims. To guide the participants, they were asked to use CER templates like the one shown in Figure 1. *CER tests*

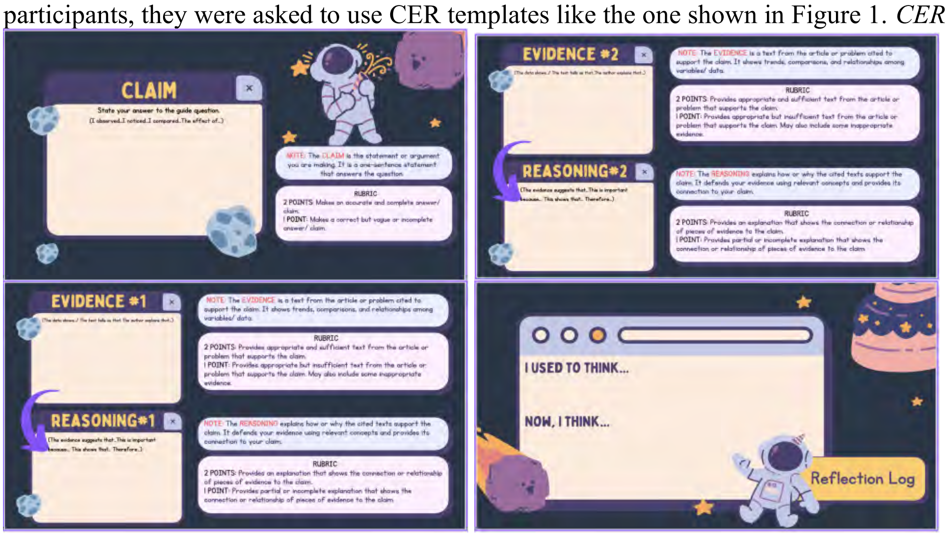
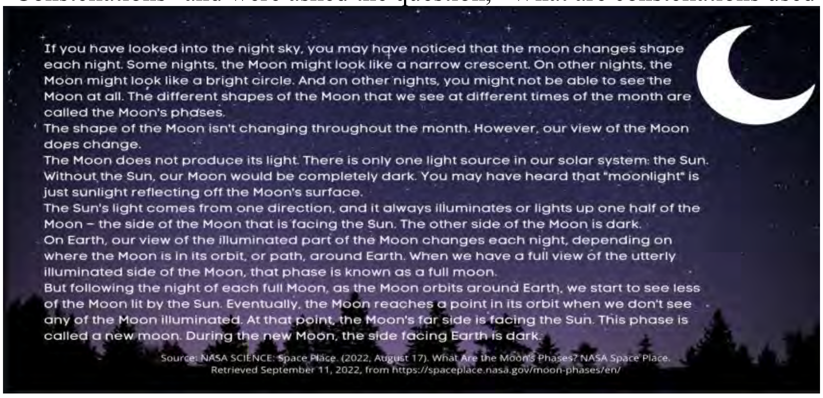


Figure 1
A sample CER template

During the implementation stage of the study, participants engaged in two CER activities as part of the meaning-making phase. Specifically, participants read an excerpt from “The Moon’s Effect on Earth’s Tide” and “The Sun Effect on Earth’s Tide” (see Figure 2) and were asked to answer the question, “Do the moon and sun affect the Earth’s oceans?”. Additionally, participants read about "Constellations" and were asked the question, “What are constellations used for?”.


If you have looked into the night sky, you may have noticed that the moon changes shape each night. Some nights, the Moon might look like a narrow crescent. On other nights, the Moon might look like a bright circle. And on other nights, you might not be able to see the Moon at all. The different shapes of the Moon that we see at different times of the month are called the Moon's phases.

The shape of the Moon isn't changing throughout the month. However, our view of the Moon does change.

The Moon does not produce its light. There is only one light source in our solar system: the Sun. Without the Sun, our Moon would be completely dark. You may have heard that "moonlight" is just sunlight reflecting off the Moon's surface.

The Sun's light comes from one direction, and it always illuminates or lights up one half of the Moon – the side of the Moon that is facing the Sun. The other side of the Moon is dark.

On Earth, our view of the illuminated part of the Moon changes each night, depending on where the Moon is in its orbit, or path, around Earth. When we have a full view of the utterly illuminated side of the Moon, that phase is known as a full moon.

But following the night of each full Moon, as the Moon orbits around Earth, we start to see less of the Moon lit by the Sun. Eventually, the Moon reaches a point in its orbit when we don't see any of the Moon illuminated. At that point, the Moon's far side is facing the Sun. This phase is called a new moon. During the new Moon, the side facing Earth is dark.

Source: NASA SCIENCE: Space Place. (2022, August 17). What Are the Moon's Phases? NASA Space Place. Retrieved September 11, 2022, from https://spaceplace.nasa.gov/moon-phases/en/

NASA (2022)
Figure 2
An excerpt from the article phases of the moon

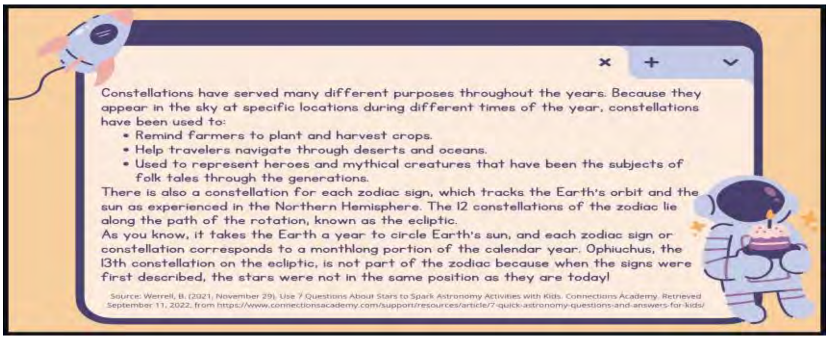
To assess the effectiveness of the CER activities in promoting scientific reasoning skills among elementary school students, participants were given a pre/post-test. During the pre/post-test, participants were instructed to read a section of the article "What Are the Moon's Phases?" (NASA, 2022) and answer the focus question, "What causes the phases of the moon?" (see Figure 3).

The test is scored based on the proposed rubric by McNeill and Krajick (2011) (see Table 1). Each component (claim, evidence, reasoning) is rated. Two points are the highest score, and zero points are the lowest.

Table 1
Argumentation skill rubric

Components	0 points	1 point	2 points
Claim	Does not make a claim or makes an inaccurate claim.	Makes an accurate but vague or incomplete claim.	Makes an accurate and complete claim.
Evidence	Does not provide evidence or only provides inappropriate evidence (evidence does not support the claim).	Provides appropriate but insufficient evidence to support the claim. May include some inappropriate evidence	Provides appropriate and sufficient evidence to support the claim
Reasoning	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.	Repeats evidence and links it to some scientific principles, but not sufficient	Provides accurate and complete reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles

Adapted from McNeill and Krajick (2011)


Constellations have served many different purposes throughout the years. Because they appear in the sky at specific locations during different times of the year, constellations have been used to:

- Remind farmers to plant and harvest crops.
- Help travelers navigate through deserts and oceans.
- Used to represent heroes and mythical creatures that have been the subjects of folk tales through the generations.

There is also a constellation for each zodiac sign, which tracks the Earth's orbit and the sun as experienced in the Northern Hemisphere. The 12 constellations of the zodiac lie along the path of the rotation, known as the ecliptic.

As you know, it takes the Earth a year to circle Earth's sun, and each zodiac sign or constellation corresponds to a monthlong portion of the calendar year. Ophiuchus, the 13th constellation on the ecliptic, is not part of the zodiac because when the signs were first described, the stars were not in the same position as they are today!

Source: Werrell, B. (2021, November 29). Use 7 Questions About Stars to Spark Astronomy Activities with Kids. Connections Academy. Retrieved September 11, 2022, from https://www.connectionsacademy.com/support/resources/article/7-quick-astronomy-questions-and-answers-for-kids/

(Warrell, 2021)
Figure 3
Excerpt from the article constellations

Survey

The survey aims to collect students' perceptions of the usefulness of the CER activities on phases of the moon and constellations. There are two questions which are as follows:

1 *Did the CER framework help you connect the learning materials and concepts we learned in class?*

2 *Did you find the CER template helpful in organizing your thoughts before writing your explanations?*

Phases of the Moon and Constellations Module

The teacher-researchers developed a unit plan on The Sky with a content focus on the Phases of the Moon and Patterns of Stars/ Constellations. It was based on the learning competencies of the K-12 Curriculum Guide, particularly in demonstrating an understanding of the moon's phases and the position of the moon and stars to debunk local myths about them. The lesson plan in this study follows an inquiry approach. Llewellyn and Ullock (2017), Kennedy and Folkes (2018), Nageotte et al. (2018) demonstrated that the CER framework in an inquiry-based approach is effective in honing students' scientific argumentation skills and promoting student conceptual understanding.

Data Collection

The conceptual and argumentation skill tests were administered at the start and end of the implementation stage. The conceptual test consisted of multiple-choice questions to collect quantitative data on the student's conceptual understanding of the phases of the moon and constellations. The CER test consisted of an open-ended question for students to express their thoughts and ideas in a structured manner based on the presented article about the moon's phases.

The open-ended questions were asked as a group to collect data on the students' perceptions of CER, but each student answered all two questions.

Data Analysis

The quantitative data collected from the pre/post-test about the phases of the moon and constellations and the argumentation skills test were analyzed using descriptive statistics such as frequency, means, and standard deviation to summarize the data.

The qualitative data collected from the open-ended questions were analyzed through content analysis. According to Krippendorff (2013), content analysis is a research method used to examine qualitative data systematically by categorizing it into themes, concepts, or codes. This method involves identifying and analyzing patterns in data, such as recurring ideas, common themes, or shared attitudes.

Research Procedure

The unit lesson was divided into two parts: phases of the moon and constellations. During the implementation of this study, the school implemented an alternating hybrid modality. This entailed a weekly rotation between face-to-face and online sessions. Face-to-face sessions occurred one week, followed by online sessions conducted via a video conference application the next week. Each week consisted of only four meetings due to a designated mid-week break on Wednesdays. This break was exclusively reserved for co-curricular activities, interest clubs, and wellness engagements.

The discussions and activities about the moon's phases were during the face-to-face sessions. At the beginning of the lesson, participants completed a pre-test on phases of the moon and constellations and an argumentation skills test. The teacher, presented the learning objectives for the moon's phases to the class, followed by two videos about the phases of the moon and three book exercises to reinforce learning. A simple laboratory activity called the Oreo Phases of the Moon was conducted to further enhance participants' understanding of the topic. Subsequently, participants completed a 10-item formative assessment to evaluate their understanding of the moon's phases.

The lesson then continued with four activities via station rotation. At Station 1, participants engaged in a CER activity where they answered a question about the moon's influences using the CER template. Station 2 involved a virtual reality activity where participants watched a lunar eclipse and described what happened during the event. Station 3 was another virtual reality activity where participants watched a solar eclipse and answered questions about the event. At Station 4, participants engaged in a drawing activity illustrating the arrangements of the sun, moon, and earth during eclipses. Finally, a 15-item formative assessment was conducted at the end of the phases of the moon lesson to gauge participants 'understanding.

The second part of the unit lesson happened in the online sessions. It began with presenting the objectives to the class. Participants were then introduced to constellations and the arrangement of the stars through an online Stellarium, followed by reading the constellations' legends and watching the constellations' history. Three book exercises were completed, followed by videos about the importance of constellations and the zodiac signs.

The discussions of the second part continued until the following week. Participants answered a question about the constellations using the CER template, followed by a formative assessment to check their understanding.

Lastly, within the same week, the students took the post-test on phases of the moon and constellations and argumentation skills test to evaluate their learning. Additionally, the students were asked to answer open-ended questions about their perceptions of the usefulness of the CER activities on phases of the moon and constellations.

Overall, the instruction was carried out for 12 meetings; each meeting was 1 hour. The lesson was structured to provide participants with multiple opportunities to engage with the content using a variety of activities, assessments, and technologies. Puspitarani and Hanif (2019) highlighted the need for alternative methods to enhance student learning motivation, suggesting incorporating technology in the learning process as one viable approach. Both pre- and formative assessments allowed the researchers to evaluate participants' understanding before and after the lesson, while the station rotation format and use of technology were intended to promote engagement and active participation.

The teacher, who was also one of the researchers, had received specialized training on implementing the Claim-Evidence-Reasoning (CER) framework in the classroom from the school's academic consultant. This training thoroughly prepared the teacher for effectively integrating the CER methodology into the lesson.

FINDINGS AND DISCUSSION

CER Pre-test and Post-test

Figure 4 shows the frequency of scores the elementary school students received in the pretest and posttest of the Claim-Evidence-Reasoning (CER) activities. The CER activities were designed to promote the students' scientific reasoning skills in the phases of the moon and constellations.

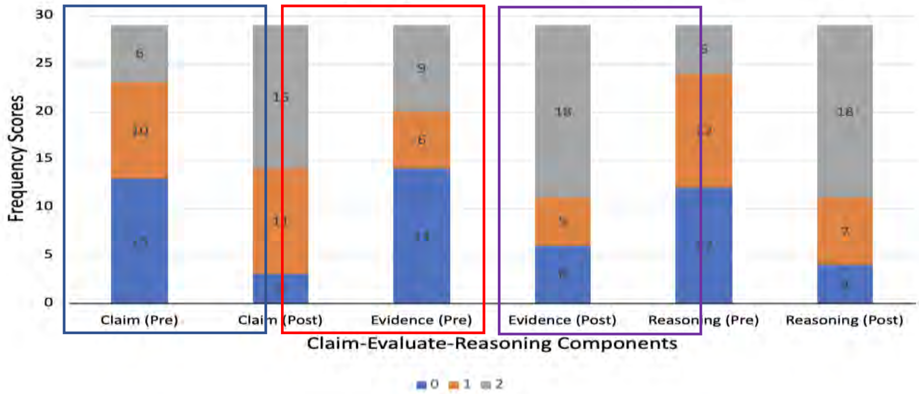


Figure 4
Comparison of pre-test and post-test frequency scores of CER components

The results of the pretest and posttest frequency scores in claim-evidence-reasoning provide valuable insights into the effectiveness of the claim-evidence-reasoning (CER) activities in promoting the scientific reasoning skills of elementary school students in phases of the moon and constellations.

It can be seen in the pretest results that a significant number of students scored low in all three categories, with 13 students scoring 0 points in the claim, 14 students scoring 0 points in the evidence, and 12 students scoring 0 points in the reasoning section. This suggests that many students needed more fundamental skills to engage in scientific reasoning, such as making claims and supporting them with evidence.

However, the post-test results show a marked improvement in all three categories, with fewer students scoring 0 points in each category. For example, only three students scored 0 points in the claim section, compared to 13 in the pretest. Similarly, the number of students scoring 0 points in the evidence and reasoning categories also decreased significantly, indicating that the CER activities positively impacted the students' scientific reasoning skills.

The posttest results also show an increase in the number of students who scored 2 points in each category, indicating that the CER activities effectively promoted higher-order thinking skills among the students. This is particularly noteworthy in the evidence and reasoning categories, where a significantly higher number of students scored 2 points in the posttest compared to the pretest.

Overall, the results of the pretest and posttest frequency scores in claim-evidence-reasoning suggest that the CER activities effectively promote scientific reasoning skills among elementary school students in phases of the moon and constellations. The findings of this research article have significant implications for science educators and curriculum designers, as it highlights the importance of incorporating CER activities in science education to promote higher-order thinking skills among students.

Table 2
Comparison of pre-test and post-test mean and standard deviation

Descriptive Statistics	Pretest	Posttest
Mean	2.34	4.31
Standard Deviation	1.78	1.63

The results of the claim-evidence-reasoning pretest and posttest scores indicate a significant improvement in the participants' argumentation skills. The average pre-test score of 2.34 and the standard deviation of 1.78 suggest that the participants had a weak understanding of claim-evidence-reasoning prior to the intervention. However, the post-test average score of 4.31 and the standard deviation of 1.63 show a substantial improvement in their argumentation skills.

Surveys

Below are the results of the survey. The survey included two questions: whether the CER framework helped students connect learning materials and concepts and whether the CER template helped organize students' thoughts before writing their explanations.

Question 1: Did the CER framework help you connect the learning materials and concepts we learned in class?

Using the CER framework helped me write [explanations] in Science. It expanded my knowledge [of] writing paragraphs and really helped me improve my paragraph construction and how I reason out.

Using the CER framework helped me make connections between the learning materials used and concepts that we learned in class. It helped me relate facts ... we learned in class and how it is applicable to our daily lives.

The CER Framework helped me describe and apply the learnings to [day-to-day] experiences. It helped me make sure my observations [were] validated with facts….

The responses suggest that the CER framework helped students connect the learning materials and concepts they learned in class. Many students mentioned that the framework helped them organize their thoughts and make connections between claims, evidence, and reasoning. Some students also mentioned that the framework helped them relate the concepts they learned to real-life applications. However, a few responses did not directly answer the question or were unclear in their explanation.

Question 2: Did you find the CER template helpful in organizing your thoughts before writing your explanations?

Yes, I found the CER template helpful in organizing my thoughts before writing my explanations. We should write our claim first and look for [evidence] that will support it. Then make a connection between the claim and the [evidence] through reasoning [afterward.]

Yes, it was helpful in organizing my thoughts. My claim is like my topic sentence. My [pieces of] [evidence are] my examples, and the reasoning is my explanation.

The students’ responses suggest that the CER (Claim-Evidence-Reasoning) template helped organize the students' thoughts before writing their explanations. Some students agreed with a simple "yes," while others elaborated on how the template helped them. Specifically, they found the template useful in structuring their claims, evidence, and reasoning and planning their responses. Some students equated the CER template with organizing a paragraph or an essay. The claim is the topic sentence, the pieces of evidence are the examples, and the reasoning is the explanation.

The second guideline prompts students to articulate their topic comprehension by constructing a clear and succinct statement or argument. The third guideline mandates that students utilize the cited text or problem to substantiate their claims and demonstrate patterns, comparisons, and correlations among data points. Additionally, this cultivates critical reading skills by requiring students to extract and apply relevant information from the text. The fourth guideline challenges students to justify their evidence by linking pertinent concepts to their initial claim. These guidelines aimed to foster a deeper understanding of the topic and encourage critical thinking skills. This supports the assertions of Kennedy and Folkes (2018) that using key phrases is helpful for students to express their ideas clearly and of Wallon et al. (2018) emphasizing the necessity of explicit instruction and support from the teacher. Overall, the student's responses indicate that the CER template effectively promotes clear and logical organization of thoughts in science writing.

The quantitative and qualitative data suggest that the CER activities effectively promote scientific reasoning skills among elementary school students in phases of the moon and constellations. The quantitative data showed a marked improvement in all three categories of claim, evidence, and reasoning in the post-test compared to the pretest. Figure 4 shows that the number of students scoring 0 points in each category decreased significantly, while the number of students scoring 2 points in each category increased, indicating the effectiveness of the CER activities in promoting higher-order thinking skills. Additionally, Table 2 shows that the post-test mean score of 4.31 was significantly higher than the pre-test mean score of 2.34, suggesting that the students made significant progress in their argumentation skills. The responses also indicate that the CER template effectively promotes clear and logical organization of thoughts in science writing.

Overall, the triangulation of quantitative and qualitative data suggests that the CER activities effectively promote scientific reasoning skills among elementary school students and highlight the importance of incorporating CER activities in science education to promote higher-order thinking skills. These discoveries resonate and align with the findings of Llewellyn & Ullock (2017), Nageotte et al. (2018), Wallon et al. (2018), Short et al. (2020), and Atkinson et al. (2020).

CONCLUSION

The findings of this study indicate that the Claim-Evidence-Reasoning (CER) framework effectively promotes scientific reasoning skills among elementary school students. The quantitative data showed a significant improvement in students' ability to construct claims, evidence, and reasoning after using the CER framework. The qualitative data also supported the quantitative findings, with students reporting that the CER framework helped them connect learning materials and concepts and organize their thoughts before writing explanations. Based on the current studies, the researchers believe that the Claim-Evidence-Reasoning (CER) strategy in instruction could be a valuable tool in helping the students achieve their learning goals in Meaning Making and assessing their competency in analysis.

The results in this study highlight the importance of incorporating CER activities in science education to promote higher-order thinking skills such as scientific reasoning, a critical skill for students to develop to become informed and engaged citizens in the 21st century.

As the second researcher continued to implement the lesson using the CER strategy, she was mindful of the challenges her students faced, particularly in identifying the focus of the problem, writing clear claims, and reasoning based on evidence. She continued to provide explicit guidance, clarify misconceptions, and offer support to help her students develop competency in analysis and reasoning using the CER strategy. Through reflection and continuous improvement, she was committed to facilitating meaningful learning experiences that promote critical thinking and achieving learning goals.

Implementing the CER strategy at the meaning-making level has been a rewarding experience. Seeing the students' progress in identifying keywords, writing concise claims, recognizing evidence, reasoning effectively, and connecting their claims with evidence was fulfilling. The researchers look forward to continuing to hone students' critical thinking and analysis skills through ongoing practice and refinement of the CER approach.

However, it is important to note that the sample size of this study was small (n=29), and the implementation was limited to the topics of phases of the moon and constellations for only 12 meetings. Therefore, future research is needed to investigate the generalizability of these findings to other topics over longer periods. Additionally, it would be valuable to explore how the CER framework can be adapted and implemented in different contexts and grade levels to promote scientific reasoning skills further.

IMPLICATIONS

The effective application of the CER framework within the classroom setting yields the following significant implications for educational practice:

1 Using terms, prompts, and rubrics within the CER template furnishes students with a structured approach to effectively organizing their thoughts and refining their ideas. This structured framework not only aids in articulating claims but also fosters the development of robust reasoning skills, thereby nurturing cognitive growth.

2 Integrating supplementary resource materials, such as video clips and images, can enhance students' capacity to extract evidence from varied sources. This diversified approach to evidence-gathering broadens their understanding and cultivates critical analysis skills across multiple media forms.

3 Properly training educators to implement the CER framework in classrooms is essential for its success. With comprehensive training, teachers play a pivotal role in guiding students through the nuanced layers of the CER strategy. This guidance ensures effective implementation and fosters an environment that enhances critical thinking and analytical skills.

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