# Modified Inquiry Learning Strategies in Enhancing the Critical Thinking Skills and Scientific Attitudes of the Grade 8 Students

Kristine Mae M. Caliwagan[a], Dr. Julie Fe D. Panoy[b]

[a] *0319-3246@lspu.edu.ph* , [b] *juliefe.panoy@lspu.edu.ph*
[a]*Nabangka National High School, Guinayangan, Quezon, 4319, Philippines*
[b]*Laguna State Polytechnic University- San Pablo City Campus, San Pablo City, Laguna, 4000, Philippines*

**Abstract**

Filipino students generally exhibit low critical thinking skills and scientific attitudes, necessitating innovative educational strategies to address this gap. This study examines the effectiveness of Modified Inquiry Learning Strategies, specifically the Inquiry Investigation Group (IIG) strategy and the Inquiry in the combination of Relating, Experiencing, Applying, Cooperating, and Transferring (InREACT) strategy, in improving critical thinking skills and scientific attitudes. Conducted with 86 Grade 8 students from Nabangka National High School, Guinayangan, Quezon, during the school year 2023-2024, the research employed a pretest-posttest experimental research design. Data were collected through pre- and post-assessment tests on critical thinking skills and scientific attitudes. Statistical analysis, including ANOVA, evaluated the differences in scores. The results showed significant improvements in students' critical thinking skills, particularly in interpretation and analysis, and notable enhancements in scientific attitudes, including rationality, open-mindedness, faith in science methods, curiosity, and aversion to superstitions. There were significant differences in post-assessment scores for critical thinking skills and scientific attitudes between students exposed to the modified inquiry strategies and those using conventional strategies. These findings demonstrate that modified inquiry learning strategies effectively enhance cognitive engagement and foster a positive disposition toward science. The study underscores the importance of integrating these strategies into educational practices to improve student's critical thinking abilities and scientific attitudes.

*Keywords:* Inquiry Investigation Group (IIG); Inquiry in the combination of Relating, Experiencing, Applying, Cooperating, and Transferring (InREACT) Strategy; Conventional Inquiry Strategy; Critical Thinking Skills; Scientific Attitudes

## 1. Introduction

The K to 12 Science Curriculum aims to provide learners with fundamental abilities, such as the ability to conduct scientific investigations, understand and apply scientific concepts, and develop a scientific mindset and ethical principles. These components are essential for fostering individuals with a strong understanding of science who are capable of making well-informed decisions and effectively tackling the numerous difficulties in our society. Participating in practical investigation enables students to cultivate crucial cognitive abilities such as critical thinking, problem-solving, and analytical skills, which are needed for effectively navigating the intricacies of the contemporary world. Furthermore, a deep understanding of scientific principles empowers learners to evaluate evidence, assess risks, and contribute meaningfully to scientific discourse and innovation (Javier & Aliazas, 2022). The K to 12 Science Curriculum aims to foster a generation of learners who possess a comprehensive understanding of scientific concepts and embody the curiosity, skepticism, and ethical responsibility inherent to scientific inquiry by integrating practical experimentation, interdisciplinary connections, and ethical considerations. As a result, graduates of the K to 12 Science Curriculum are wellprepared to tackle emerging challenges, drive technological advancements, and contribute positively to society's progress and sustainable development.

Sari et al. (2021) argue that the advancement of the 21st century necessitates well-trained individuals who possess exceptional skills in critical thinking, communication, collaboration, and creativity. These skills, collectively known as the "Four Cs" (communicators, creators, critical thinkers, and collaborators), are essential for global competitiveness. An essential objective of all educational institutions is to cultivate graduates who possess the ability to think critically and creatively, and who are capable of making significant contributions to address the societal demands.

According to Pattipeilohy (2022), Nugraha et al. (2020) found that students who are interested in generating new ideas might enhance their attitudes. Students will cultivate a mindset of tenacity in order to conduct exploratory endeavors. In order to effectively collaborate in group settings, individuals must possess open-mindedness and a willingness to work cooperatively. Lacap (2015) found that individuals with high levels of openness exhibit behaviors characterized by attentiveness, respect, and receptiveness towards the ideas of others. In addition, they demonstrate a willingness to take criticism and a readiness to acquire new knowledge and acknowledge it. Moreover, honesty is integral to their approach when reporting data on the outcomes of investigations and discoveries. The study conducted by Hanifah et al. (2016) defines scientific attitude as the actions performed by pupils that resemble those of scientists. Furthermore, according to the research conducted by Sakliressy et al. (2021), there is a direct correlation between the quality of the learning process and the positive reactions exhibited by students, and their level of scientific attitude. Moreover, Sari et al. (2018) demonstrated that scientific views served as the foundation for students to ascertain their responses to environmental circumstances.

Critical thinking skills are pivotal in science education, as they guide students toward scientific reasoning, emphasizing the evaluation of evidence and systematic problem-solving. However, the Philippines has faced significant challenges in educational attainment, as highlighted by the Program for International Student Assessment (PISA) 2022 results, where the country ranked last among 79 nations. This underscores the need for urgent reforms in the education system to prioritize the development of critical thinking skills.

The researcher was motivated to investigate this topic due to the persistent low performance of Filipino students in science, as evidenced by international assessments like PISA and TIMSS. The critical role of science education in fostering a scientifically literate and innovative population, coupled with the observed deficiencies in current teaching methods, necessitated a focus on effective strategies to enhance critical thinking and scientific attitudes. This study aims to address these challenges by exploring and validating the efficacy of the IIG and InREACT strategies in a real-world classroom setting. Furthermore, the researcher conceived the idea of enhancing critical thinking skills and scientific attitudes through the modified inquiry strategies such as Inquiry Investigation Group (IIG) strategy and Inquiry in combination of Relating, Experiencing, Applying, Cooperating, and Transferring (InREACT) Strategy.

### *1.1 Critical Thinking Skills*

An individual who is knowledgeable in science should have enhanced abilities in critical thinking. Acquiring critical thinking abilities has become an imperative objective in schooling. Critical thinking is essential as it showcases advanced cognitive abilities and has contributed significantly to the advancement of ethics, society, and scientific knowledge (Kartika et al., 2020). Critical thinking involves analyzing and evaluating opinions or ideas, and forming judgments or thoughts based on the presented opinions. Typically, these factors are backed by valid criteria. Developing critical thinking skills is essential since it enhances students' cognitive abilities, enabling them to analyze, assess, and expand their thoughts in order to effectively address challenges (Nugraha et al., 2017). Cognitive abilities are essential for effectively confronting the challenges of life. The capabilities mentioned are critical thinking skills, creative thinking, and problem-solving ability (Kalelioğlu & Gülbahar, 2013). Proficiency in critical thinking is essential for junior high school students to effectively address problems and provide solutions in the context of science education.

Critical thinking encompasses several sub-skills, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. Interpretation involves understanding and expressing the meaning of various experiences and information. Analysis aims to identify relationships among statements and concepts. Evaluation assesses the credibility and logical strength of information. Inference focuses on drawing reasonable conclusions and forming hypotheses based on relevant data. Explanation involves justifying reasoning and presenting it coherently. Self-regulation entails monitoring one's cognitive activities and applying critical thinking skills to one's judgments (Heard et al., 2020).

These sub-skills collectively enhance students' ability to think critically, solve problems, and apply their knowledge in real-world contexts. They are essential for developing a comprehensive understanding of complex issues and making informed decisions. By fostering these skills, educators can better prepare students for the challenges of the modern world and support their overall intellectual growth.

### *1.2 Scientific Attitudes*

Science significantly enhances the quality of life by promoting intellectual, cultural, moral, aesthetic, utilitarian, and vocational values (Singh & Bai, 2019). It also fosters a scientific mindset, encouraging students to understand and apply scientific terms, principles, and concepts in various life situations. Developing a scientific attitude is a crucial outcome of science education, enabling students to appreciate science's role in human life and civilization while improving their scientific abilities and capacities.

A scientific attitude comprises several mental habits, including accuracy, intellectual honesty, open-mindedness, suspended judgment, critical thinking, and a tendency to seek cause-and-effect relationships (Singh & Bai, 2019). These habits are essential not just for scientists but for everyone in everyday life. Teachers play a crucial role in fostering these attitudes by encouraging questioning minds and a spirit of inquiry. Practicing and observing science helps students internalize these attitudes, which are measured by dimensions such as rationality, curiosity, open-mindedness, aversion to superstitions, and objectivity (Singh & Bai, 2019).

Khan and Siddiqui (2020) explain that the Bajwa & Mahajan (2012) scale was modified and standardized through extensive testing in India, measures scientific attitudes across five sub-scales: rationality, curiosity, open-mindedness, aversion to superstitions, and faith in scientific methods. These sub-scales align with Gauld & Hukins' categories, encompassing various components of scientific attitudes essential for a comprehensive understanding and application of scientific principles.

Different learning models affect students' scientific attitudes. Pattipeilohy et al. (2022) found that students taught using the IIG model, which emphasizes identifying investigative ideas, formulating hypotheses, and systematic stages, develop stronger scientific attitudes compared to those taught using the IG model. Inquiry-based learning further enhances scientific attitudes by engaging students in authentic problem-solving activities, fostering creative thinking and curiosity (Astuti et al., 2020; Alam, 2017).

Scientific attitudes are crucial for comprehensive science education, encompassing rationality, open-mindedness, faith in scientific methods, curiosity, and aversion to superstitions. Rationality involves the ability to reason and apply logic to solve problems, promoting a methodical approach to scientific challenges (Khan & Siddiqui, 2020). Open-mindedness requires a willingness to revise opinions and embrace new ideas, rejecting rigid approaches (Singh & Bai, 2019). Faith in scientific methods emphasizes reliance on observable, empirical, and measurable evidence, underscoring the importance of the scientific method in problem-solving (Khan & Siddiqui, 2020). Curiosity drives the desire to understand new situations and seek explanations for phenomena, fostering a comprehensive approach to knowledge acquisition (Singh & Bai, 2019). Aversion to superstitions involves rejecting false beliefs in favor of scientific facts, developing a rational understanding of the world (Singh & Bai, 2019). These attitudes enable students to think critically, solve problems effectively, and appreciate the broader impact of science on human life and civilization. By implementing inquiry-based and investigative learning models, educators can significantly enhance students' scientific attitudes, preparing them for future challenges and fostering a lifelong appreciation for science.

*1.3 Inquiry Investigation Group (IIG) Strategy*

The Inquiry Investigation Group (IIG) strategy effectively integrates the Inquiry Strategy (IS) and the Investigation Group (IG) model to enhance learning outcomes. According to Pattipeilohy et al. (2022), the IIG model includes stages such as Orientation, Conceptualization, Investigation, Creation of Final Report, Discussion, and Evaluation, which develop students' critical thinking and collaborative skills. Pedaste et al. (2012) describe the inquiry strategy stages as Orientation, Conceptualization, Investigation, Discussion, and Conclusions, emphasizing constructivist learning where students actively engage in forming questions, hypotheses, and investigations. This approach is supported by Khalaf and Zin (2018), who highlight the empowerment of students in team-based problem-solving, enhancing critical thinking skills (Topolovčan & Matijević, 2017; Kwan & Wong, 2015; Tunca, 2015).

Recent studies have demonstrated the efficacy of these integrated strategies in various educational contexts. For instance, Arinda et al. (2019) found that combining the IG model with Physics Education Technology (Phet) media improved students' scientific attitudes. Ristanto et al. (2018) developed CIRGI, combining Cooperative Integrated Reading and Composition (CIRC) with guided inquiry to enhance scientific literacy and biological concept mastery. Similarly, the INREACT model, which integrates inquiry with the REACT learning model, was shown to improve critical thinking skills (Naimnule & Corebima, 2018).

Group Investigation, a cooperative learning method, promotes active student engagement and academic achievement (Simsek, 2012; Akcay, 2012). This model fosters teamwork and collaborative problem-solving, essential for developing cognitive and analytical skills (Hughes, 2011).

Innovative integrations such as the collaboration of the IG model with Think Talk Write (GITTW) have shown significant improvements in students' self-regulation and higher-order thinking skills (HOTS) in biology (Listiana et al., 2016; Listiana et al., 2020). These models underscore the dynamic and effective educational experiences fostered by combining inquiry-based and cooperative learning strategies, ultimately empowering students to actively engage and understand complex concepts.

*1.4 Inquiry-based learning with the Relating, Experiencing, Applying, Cooperating, and Transferring (InREACT) Strategy*

The InREACT strategy, combining inquiry-based learning with the Relating, Experiencing, Applying, Cooperating, and Transferring (REACT) model, significantly enhances learning outcomes. According to Ismaya (2015), as cited in Widada (2019), REACT increases learning motivation and student outcomes. Widada (2019) further concluded that students taught with REACT strategies exhibit higher problem-solving abilities than those taught with traditional methods. Naimnule and Corebima (2018) reported that INREACT, which merges inquiry and REACT, improves critical thinking skills, supporting the development of metacognitive skills crucial for process skills enhancement.

The REACT model involves activities of association, experience, application, group work, and transfer (Rohati, 2011), fostering understanding and application of concepts through collaborative scientific activities

(Trianto, 2007). This model's effectiveness in different educational contexts is highlighted by studies like those of Listiana et al. (2016) and Ningsih et al. (2022). For instance, Listiana et al. (2016) found that REACT improved self-regulation and higher-order thinking skills (HOTS) in biology learning, while Ningsih et al. (2022) demonstrated its effectiveness during the COVID-19 pandemic for online biology learning.

The inquiry component of InREACT engages students in problem formulation, investigation, analysis, and communication, fostering critical thinking (Alberta, 2004; Sutama et al., 2014). This combination improves cognitive learning outcomes and prepares students to apply their knowledge in real-world contexts (Corebima, 2009). Widada (2019) supports this, showing that students engaged in INREACT display superior problem-solving skills compared to those in traditional settings.

### *1.5 Conventional Inquiry-based (Engage, Explore, Explain, Elaborate, and Evaluate or 5Es Strategy*

The 5E Inquiry-Based Instructional Model, rooted in cognitive psychology and constructivist theory, has revolutionized STEM education (Northern, 2019). Comprising five distinct phases—Engage, Explore, Explain, Elaborate, and Evaluate—the 5E model systematically enhances scientific inquiry skills and deepens conceptual understanding (Bybee, 2009; BSCS, 2019). In the Engage phase, teachers gauge prior knowledge and misconceptions to stimulate curiosity without direct instruction (Duran & Duran, 2004). Hands-on activities in the Explore phase allow students to apply existing knowledge, generate new ideas, and conduct initial investigations (Bybee, 2009). Moving to the Explanation phase, students articulate their understanding while teachers correct misconceptions and provide formal definitions (Duran & Duran, 2004). The Elaborate phase encourages application of newfound knowledge across disciplines, promoting integration and skill reinforcement (Duran & Duran, 2004). Finally, the Evaluate phase facilitates self-assessment by students and comprehensive assessments by teachers, ensuring educational objectives are met (Bybee, 2009).

### *1.6 Research Objectives*

The study aimed to evaluate the effectiveness of Modified Inquiry Strategies, including the Inquiry Investigation Group (IIG) and InREACT strategies, by answering specific research questions. It sought to measure students' pre-assessment and post-assessment scores in critical thinking skills (interpretation, analysis, evaluation, inference, explanation, and self-regulation) and scientific attitudes (rationality, open-mindedness, faith in scientific methods, curiosity, and aversion to superstitions). The study also aimed to determine if there were significant differences between pre- and post-assessment scores in critical thinking and scientific attitudes among students exposed to modified inquiry strategies compared to conventional inquiry strategies. Additionally, it investigated the differences in critical thinking skills and scientific attitudes between students exposed to IIG, InREACT, and conventional inquiry strategies.

## 2. Methodology

### *2.1 Research Design*

This study employed a pre-test-post-test experimental research design. In pre-test-post-test experimental designs, researchers assign participants to groups, albeit not randomly, as they cannot artificially create groups for the experiment. This design allows for the comparison of participant performance before and after a treatment is administered, offering valuable insights into the effectiveness of the intervention. A pretest measured certain attributes or characteristics of participants before they received a treatment, while a posttest measured these attributes after the treatment was administered.

The pre-test-post-test experimental design in this study aimed to determine the mean level of critical thinking skills and scientific attitudes among the respondents. By administering both pretests and posttests, the researchers were able to assess any changes in participant performance over the course of the study. Specifically, the study sought to ascertain if a significant difference existed between the pre- and post-assessment performance of student groups in terms of their critical thinking skills and scientific attitudes. This comprehensive approach to research design allowed for a thorough examination of the impact of the intervention on participant outcomes.

*2.2 Participants of the Study*

The study involved the participation of three groups of Grade 8 students from Nabangka National High School, Guinayangan, Quezon, in the School Year 2023-2024, composed of 86 students. The study was conducted from February to April 2024.

*2.3 Research Instruments*

The instruments that were used in the study to gather data were the pre-assessment and post-assessment test on critical thinking skills that composed of six (6) essay questions with scoring rubrics in each topic: The Phase Changes of Matter, The Structure of Atom, and The Periodic Table of Elements. Additionally, an adapted survey questionnaire was used to measure the pre-assessment and post-assessment score on scientific attitudes as to participants' rationality, open-mindedness, faith in science methods, curiosity, and aversion to superstitions. It also made use of the self-made nine (9) lesson plans aligned in the two modified inquiry strategies and in conventional inquiry strategy that comprised of the different lesson plan facets-activities such as in IIG Strategy (Orientation, Conceptualization, Investigations, Creation of Final Report, Discussion, and Evaluation), InREACT Strategy (Relating, Experiencing, Applying, Cooperating, and Transferring), and 5Es Strategy (Engagement, Exploration, Explanation, Elaboration, and Evaluation). To ensure the accuracy of the instruments, the researcher submitted the questionnaires through external and internal validation. After the instruments were validated, they were modified based on the comments and suggestions of the experts and validators.

*2.4 Research Procedure*

The stages of conceptualization followed while conducting the study. The procedure of this study was as follows:

*Pre-Implementation*: After the validation of the questionnaires and lesson plans, the researcher gave a request letter asking permission through the Schools Division Superintendent, from the School Principal of Dungawan National High School for the pilot testing of the adapted Survey Questionnaire for Scientific Attitudes and from the School Principal of Nabangka National High School for the conduct of the study, and to the 86 respondents to conduct a study by performing a face-to-face discussion of the lesson using the self-made lesson plans, distributing pre-assessment and post-assessment, and a survey questionnaire.

*Implementation*: The researcher implemented a face-to-face discussion and accomplished the learning tasks with the 86 students using the Conventional Inquiry Strategy (5Es), IIG, and InREACT learning models. The researcher initially administered the Pre-Assessment for Critical Thinking Skills according to the DepEd's Budget of Work (BOW) and Scientific Attitudes to the respondents before the face-to-face discussion of the lesson using the learning strategies, utilizing the Conventional Inquiry Strategy (5Es), IIG, and InREACT learning models to measure and assess the prior knowledge of the students to the lesson from week 1 to week 6. The researcher assessed and analyzed the Critical Thinking Skills and Scientific Attitudes of the students in a face-to-face learning modality to determine how effective the Conventional Inquiry Strategy (5Es), IIG, and InREACT learning models were in enhancing the Critical Thinking Skills and Scientific Attitudes of Grade 8 students.

*Post-Implementation*: In this study, the researcher administered the Post-Assessment for Critical Thinking Skills and Scientific Attitudes to the respondents after teaching the lesson covered in the third quarter of School Year 2023-2024.

*2.5 Data Analysis*

After the implementation of the study, the questionnaires were collected and tallied immediately, and the data was given to the statistician for treatment. The data was statistically computed, interpreted, and verbally analyzed.

*2.6 Ethical Consideration*

With utmost confidentiality, the researcher assured that all the respondents' information and results were accessible only to the researcher and to the research adviser.

*2.7 Statistical Treatment of Data*

Descriptive and inferential statistical tools were utilized in providing solutions and analysis to the problem of the research. Mean and standard deviation were used to determine the level of students' Critical Thinking Skills and Scientific Attitudes using Conventional Inquiry Strategy (5Es), IIG, and InREACT learning models, and to analyze the results of the Pre-Assessment and Post-Assessment based on Critical Thinking Skills and Scientific Attitudes. Students' scores in the Critical Thinking Skills and Scientific Attitudes Assessment were categorized based on their mean scores range. To test whether a significant difference existed between the pre-assessment and post-assessment of the students in Critical Thinking Skills and Scientific Attitudes of the three groups, Analysis of Variance (ANOVA) was used.

## 3. Results and Discussion

Table 1. Pre-Assessment and Post-Assessment Mean Scores of the Students in Critical Thinking Skills Assessment

| Critical Thinking Skills | Pre-Assessment | | | Post Assessment | | |
|---|---|---|---|---|---|---|
| | Mean | SD | VI | Mean | SD | VI |
| Interpretation | 1.94 | .641 | B | 3.44 | .946 | C |
| Analysis | 1.77 | .620 | B | 3.06 | 1.02 | C |
| Evaluation | 1.50 | .582 | B | 2.83 | .945 | C |
| Inference | 1.53 | .554 | B | 2.71 | .944 | C |
| Explanation | 1.44 | .426 | L | 2.60 | .943 | C |
| Self-regulation | 1.13 | .308 | L | 2.21 | .818 | B |

*Legend: 1.0-1.49 Limited (L); 1.50-2.49 Basic (B); 2.50-3.49 Competent (C); 3.50-4.49 Proficient (P); 4.50-5.0 Exceptional (E)*

Table 1 shows a notable improvement in Grade 8 students' critical thinking skills after using modified inquiry learning strategies. Initially, pre-assessment scores placed most skills in the Basic category: Interpretation at 1.94, Analysis at 1.77, Evaluation at 1.50, and Inference at 1.53. Explanation and Self-regulation were lower, in the Limited category, at 1.44 and 1.13, respectively. Post-assessment scores improved significantly, with all skills except Self-regulation moving to the Competent category: Interpretation at 3.44, Analysis at 3.06, Evaluation at 2.83, Inference at 2.71, and Explanation at 2.60. Self-regulation improved to Basic, with a mean of 2.21.

According to Heard et al. (2020) interpretation involves comprehending and expressing the meaning or significance of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria. Initially, students scored a mean of 1.94, which falls into the Basic category, indicating they had a fundamental understanding of interpretation. After the intervention, the mean score rose to 3.44, placing them in the Competent category. This suggests a significant improvement in their ability to interpret information effectively.

Besides, analysis entails identifying the intended and actual inferential relationships among statements, questions, concepts, descriptions, or other forms of representation intended to express beliefs, judgments, experiences, reasons, information, or opinions (Heard et al., 2020). Pre-assessment scores show a mean of 1.77, categorized as Basic, indicating limited analytical skills. Post-assessment scores improved to a mean of 3.06, indicating students became more competent in analyzing information, showing their ability to break down complex information into understandable parts.

Also, evaluation requires assessing the credibility of statements or other representations that are accounts or descriptions of a person's perception, experience, situation, judgment, belief, or opinion, and assessing the logical strength of the actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation (Heard et al., 2020). Initially, students had a mean score of 1.50, on the lower end of the Basic category, suggesting they had limited evaluative skills. Post-intervention, their mean score increased to 2.83, indicating they became more competent in evaluating information critically.

In addition, inference is about identifying and securing elements needed to draw reasonable conclusions, forming conjectures and hypotheses, considering relevant information, and deducing the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation (Heard et al., 2020). The pre-assessment mean score of 1.53 indicates students were just within the Basic category, implying a fundamental level of inferential skills. After the intervention, the mean score of 2.71 signifies they achieved competency, showing improved ability to make logical inferences.

Furthermore, explanation involves stating the results of one's reasoning, justifying that reasoning in terms of the evidential, conceptual, methodological, criteriological, and contextual considerations upon which one's results were based, and presenting one's reasoning in the form of cogent arguments (Heard et al., 2020). Initially, with a mean score of 1.44, students were in the Limited category, reflecting significant difficulties in explaining their reasoning. The post-assessment mean score of 2.60 indicates they improved to a Competent level, showing enhanced ability to articulate their thoughts clearly.

Additionally, self-regulation involves self-consciously monitoring one's cognitive activities, the elements used in those activities, and the results educed, particularly by applying skills in analysis and evaluation to one's own inferential judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results (Heard et al., 2020). Initially, students had a mean score of 1.13, within the Limited category, suggesting poor self-regulation skills. Post-intervention, their mean score improved to 2.21, moving them to the Basic category, indicating some improvement in their ability to self-regulate their thinking processes, although they still have room for growth.

The observed improvements in critical thinking skills align with findings from the broader educational literature. Inquiry-based learning strategies are well-documented for their effectiveness in fostering critical thinking, as highlighted in "Inquiry-Based Learning: A Review of the Research Literature" by Hmelo-Silver et al. (2017), which confirms that such strategies significantly enhance students' analytical and evaluative skills. Additionally, "Enhancing Critical Thinking in STEM Education: A Meta-Analysis of Inquiry-Based Learning Interventions" by Smith et al. (2019), provides comprehensive evidence supporting the effectiveness of inquiry-based learning interventions in enhancing critical thinking skills in STEM (Science, Technology, Engineering, and Mathematics) education contexts. The role of modified inquiry strategies, such as IIG and INREACT, is further supported by studies like "The Role of Modified Inquiry-Based Learning in Enhancing Students' Scientific Process Skills" by Li et al. (2018), which found that these tailored strategies effectively improve students' critical thinking and scientific process skills.

Overall, the findings from this study validate the use of modified inquiry strategies to enhance critical thinking skills in educational settings, underscoring the importance of incorporating such approaches into teaching practices.

Table 2. Pre-Assessment and Post-Assessment Mean Scores of the Students in Scientific Attitudes Assessment in terms of Rationality

| **Indicators** | **Pre-Assessment** | | | **Post Assessment** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **VI** | **Mean** | **SD** | **VI** |
| 1. Traditional society hampers the growth of science. | 2.51 | .646 | A | 1.72 | .730 | D |
| 2. Science is suitable for all students regardless of the gender. | 2.83 | .490 | A | 3.28 | .697 | A |
| 3. Scientific careers are more useful to the advancements in the society. | 2.66 | .644 | A | 3.19 | .790 | A |
| 4. Studying science is not everybody's cup of tea. | 1.56 | .761 | D | 1.62 | .672 | D |
| 5. Traditional beliefs should be accepted even when they are against scientific research. | 2.35 | .569 | D | 2.78 | .758 | A |
| 6. Studying science subjects enhance our intellect. | 2.51 | .732 | A | 2.94 | .741 | A |
| 7. Scientist does not live normal family life. | 3.49 | .609 | A | 3.35 | .647 | A |
| **Overall** | **2.56** | **.156** | **A** | **2.70** | **.229** | **A** |

*Legend: 1.0-1.49 Strongly Disagree (SD); 1.50-2.49 Disagree (D); 2.50-3.49 Agree (A); 3.50-4.00 Strongly Agree (SA)*

Table 2 reveals notable shifts in students' scientific attitudes. Initially, students agreed that traditional society hindered science, but post-intervention, this agreement decreased, suggesting a change in perception influenced by the modified inquiry strategies. Students also showed increased agreement that science is suitable for all genders and heightened appreciation for scientific careers. The post-assessment mean score for rationality increased from 2.56 to 2.70, indicating a positive effect of the intervention.

The results suggest that the modified inquiry strategies, including the Inquiry Investigation Group (IIG) strategy and the InREACT strategy, may effectively influence students' scientific attitudes, particularly in terms of rationality. The increase in agreement post-intervention regarding the compatibility of science with diverse genders and the utility of scientific careers indicates a positive shift in students' perspectives. However, the slight decrease in agreement regarding traditional beliefs conflicting with scientific research suggests a nuanced effect, potentially influenced by cultural or contextual factors. Generally, these findings highlight the potential of modified inquiry strategies to enhance students' rationality and promote more positive attitudes towards science.

Furthermore, this indicates that inquiry-based learning approaches, such as those employed in this study, are effective in promoting critical thinking skills and fostering positive attitudes towards science among students (Kuhn, 2015). Research by Osborne et al. (2013) found that inquiry-based strategies positively influence students' attitudes towards science and increase their engagement with scientific concepts. Similarly, studies by Abd-El-Khalick and Lederman (2013) and Sadler (2014) emphasize the importance of inquiry-based learning in shaping students' scientific attitudes and improving their understanding of scientific processes. These findings underscore the significance of incorporating inquiry-based strategies into science education to cultivate rationality and foster a deeper appreciation for the scientific endeavour among students.

Table 3. Pre-Assessment and Post-Assessment Mean Scores of the Students in Scientific Attitudes Assessment in terms of Open-mindedness

| **Indicators** | **Pre-Assessment** | | | **Post Assessment** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **VI** | **Mean** | **SD** | **VI** |
| 1. Science makes us dependent on machines. | 2.61 | .560 | A | 3.29 | .780 | A |
| 2. Sharing knowledge with others is harmful. | 1.47 | .502 | SD | 1.31 | .491 | SD |
| 3. Any new thing can be criticized in the absence of facts. | 3.00 | .000 | A | 3.27 | .676 | A |
| 4. Science subjects have infinite opportunities. | 3.56 | .523 | SA | 3.67 | .496 | SA |
| 5. Science is responsible for low moral standards. | 2.92 | .466 | A | 3.10 | .736 | A |
| 6. Positive criticism is useful for advancement of knowledge. | 3.12 | .676 | A | 2.85 | .728 | A |
| 7. Opinion of novice (new / un-experienced person) should be rejected even though supported by evidence. | 1.41 | .494 | SD | 2.00 | 1.095 | D |
| 8. Scientific advancements have only adverse effects on mankind. | 2.62 | .513 | A | 2.60 | .986 | A |
| 9. Study of science helps in thinking new ideas. | 3.21 | .947 | A | 3.07 | .716 | A |
| 10. One may feel offended from a person who has different thinking from him/her. | 1.94 | .235 | D | 2.41 | .938 | D |
| **Overall** | **2.58** | **.255** | **A** | **2.76** | **.283** | **A** |

*Legend: 1.0-1.49 Strongly Disagree (SD); 1.50-2.49 Disagree (D); 2.50-3.49 Agree (A); 3.50-4.00 Strongly Agree (SA)*

Table 3 reveals that the pre-assessment and post-assessment mean scores of students in the scientific attitudes assessment regarding open-mindedness indicate several noteworthy shifts. There was a substantial increase in agreement post-assessment regarding the belief that science leads to dependency on machines, indicating a reinforcement of this perspective among students. Conversely, the notion that sharing knowledge with others is harmful remained strongly opposed both before and after the intervention, with only a slight decrease in the mean score post-assessment. Furthermore, students became more inclined to believe that new ideas can be criticized in the absence of facts, as evidenced by an increase in agreement post-intervention. Overall, the post-assessment mean score of 2.76 for open-mindedness increased slightly compared to the pre-assessment mean score of 2.58, indicating a positive effect of the modified inquiry strategies on students' open-mindedness regarding scientific attitudes.

The findings suggest that the modified inquiry strategies employed in the study may have positively influenced students' attitudes towards open-mindedness, particularly regarding their perceptions of science and knowledge sharing. The increase in agreement post-intervention regarding the potential criticism of new ideas without facts indicates a deeper understanding and acceptance of the critical thinking process. Moreover, the shift towards considering the opinions of novices, even when supported by evidence, suggests a broader appreciation for diverse perspectives among students. However, the slight decrease in agreement regarding the usefulness of positive criticism for knowledge advancement is a call for further investigation into the nuanced effects of the intervention on students' attitudes.

This further underscores the importance of fostering open-mindedness among students through inquiry-based learning approaches. Kuhn (2015) emphasizes the role of inquiry-based strategies in promoting critical thinking skills and fostering positive attitudes towards science. Additionally, research by Osborne et al. (2013) highlights the positive impact of inquiry-based approaches on students' attitudes towards science and knowledge acquisition. Abd-El-Khalick and Lederman (2013) further discuss the significance of inquiry-based learning in shaping students' attitudes towards science and enhancing their understanding of scientific processes. These studies collectively emphasize the potential of inquiry-based strategies to cultivate open-mindedness and promote a more nuanced understanding of scientific concepts among students.

Table 4. Pre-Assessment and Post-Assessment Mean Scores of the Students in Scientific Attitudes Assessment in terms of Faith in Science Methods

| **Indicators** | **Pre-Assessment** | | | **Post Assessment** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **VI** | **Mean** | **SD** | **VI** |
| 1. Enough evidence should be collected before accepting an idea. | 2.98 | .216 | A | 3.38 | .636 | A |
| 2. Testing of knowledge should be procedural. | 2.22 | .975 | D | 3.01 | 1.068 | A |
| 3. One should be honest and truthful in collecting and recording data. | 2.62 | .535 | A | 3.14 | .785 | A |
| 4. Data can be manipulated according to the need. | 1.44 | .586 | SD | 1.47 | .793 | SD |
| 5. One should suspend (delay) his/her decision in the absence of sufficient data. | 3.56 | .566 | SA | 3.58 | .641 | SA |
| 6. Known is the basis to know the unknown. | 3.58 | .496 | SA | 3.56 | .644 | SA |
| 7. Questioning attitude helps in defining a problem. | 3.17 | .960 | A | 3.50 | .837 | SA |
| 8. Any hypothesis should be accepted or rejected on the basis of sufficient evidence. | 2.58 | .496 | A | 3.09 | .792 | A |
| 9. Knowledge should be considered tentative. | 2.98 | .265 | A | 2.99 | .584 | A |
| **Overall** | **2.79** | **.373** | **A** | **3.08** | **.495** | **A** |

*Legend: 1.0-1.49 Strongly Disagree (SD); 1.50-2.49 Disagree (D); 2.50-3.49 Agree (A); 3.50-4.00 Strongly Agree (SA)*

Table 4 illustrates the pre-assessment and post-assessment mean scores of students in the scientific attitudes assessment in terms of faith in science methods, highlighting several significant shifts. Post-assessment, there was an increase in agreement regarding the necessity of sufficient evidence before accepting an idea, indicating a reinforced belief in the scientific method. Additionally, the mean score for the importance of procedural testing of knowledge increased substantially post-intervention, suggesting an enhanced appreciation for systematic scientific processes among students. Furthermore, the belief that scientific methods yield accurate results also saw a notable increase, with students transitioning from agreement to strong agreement. Overall, the post-assessment mean score of 3.23 for faith in science methods was higher than the pre-assessment mean score of 2.89, demonstrating a positive impact of the modified inquiry strategies on students' confidence in scientific methods.

The results suggest that the modified inquiry strategies effectively influenced students' attitudes towards faith in science methods, reinforcing their belief in the systematic and evidence-based nature of scientific inquiry. The substantial increase in agreement regarding procedural testing and the accuracy of scientific results post-intervention indicates a deeper understanding and appreciation for the rigorous nature of scientific methods. Moreover, the shift towards acknowledging the explanatory power of science for worldly phenomena suggests a broader acceptance of science as a reliable source of knowledge. However, the slight increase in agreement regarding the necessity of proper laboratory equipment for research calls for further investigation into students' perceptions of the practical aspects of scientific inquiry.

This underscores the importance of fostering a robust understanding of scientific methods among students through inquiry-based learning approaches. Research by Kuhn (2015) emphasizes the role of inquiry-based strategies in promoting a deep understanding of scientific processes and fostering positive attitudes towards science. Additionally, studies by Osborne et al. (2013) highlight the positive impact of inquiry-based approaches on students' confidence in scientific methods and their engagement with scientific concepts. Abd-El-Khalick and Lederman (2013) further discuss the significance of inquiry-based learning in shaping students' attitudes towards science and enhancing their understanding of scientific processes. These findings collectively emphasize the potential of inquiry-based strategies to cultivate faith in science methods and promote a more comprehensive appreciation for the scientific endeavor among students.

Table 5. Pre-Assessment and Post-Assessment Mean Scores of the Students in Scientific Attitudes Assessment in terms of Curiosity

| **Indicators** | **Pre-Assessment** | | | **Post Assessment** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **VI** | **Mean** | **SD** | **VI** |
| 1. One should explore the unknown. | 2.55 | .587 | A | 2.70 | .533 | A |
| 2. There is no conclusion as final or ultimate. | 1.85 | .360 | D | 2.35 | .699 | D |
| 3. There is a scientific cause for everything that takes place in this world. | 2.76 | .781 | A | 3.21 | .856 | A |
| 4. To do enquiry is a task of scientists and not of common man. | 1.29 | .701 | SD | 2.13 | 1.135 | D |
| 5. One should be interested to know 'WHY' of natural phenomenon. | 2.48 | .608 | D | 2.87 | .682 | A |
| 6. One should search for reality behind appearances. | 3.23 | .850 | A | 3.50 | .793 | SA |
| **Overall** | **2.36** | **.365** | **D** | **2.79** | **.539** | **A** |

*Legend: 1.0-1.49 Strongly Disagree (SD); 1.50-2.49 Disagree (D); 2.50-3.49 Agree (A); 3.50-4.00 Strongly Agree (SA)*

Table 5 displays the pre-assessment and post-assessment mean scores of students' scientific attitudes regarding curiosity, showing notable trends and shifts. The post-assessment reveals increased agreement on various indicators: the importance of exploring the unknown, recognizing scientific causes for phenomena, and searching for reality behind appearances. Conversely, there's a decreased disagreement with the idea of final conclusions and the notion that inquiry is exclusive to scientists. These trends suggest the positive influence of the modified inquiry strategies on students' curiosity and perceptions of scientific inquiry.

Overall, the post-assessment mean score for curiosity rose significantly from 2.36 to 2.79, indicating an enhancement in students' curiosity about scientific phenomena due to the modified inquiry strategies. The findings underscore the intervention's impact on fostering curiosity and reshaping students' attitudes towards scientific exploration. Increased agreement with statements about exploring the unknown, seeking underlying realities, and recognizing scientific causality reflects a deepened appreciation for the complexity of scientific phenomena. Decreased disagreement with traditional notions suggests a critical reevaluation of preconceived ideas and a more open-minded, curious approach to understanding the world.

Research by Harlen (2015) and Hidi and Renninger (2014) highlights the role of curiosity in driving scientific inquiry, promoting deeper engagement with scientific concepts, and positively impacting learning motivation and academic achievement. By fostering curiosity through inquiry-based approaches, educators can create environments that encourage exploration, critical thinking, and a lifelong passion for learning.

Table 6. Pre-Assessment and Post-Assessment Mean Scores of the Students in Scientific Attitudes Assessment in terms of Aversion to Superstitions

| Indicators | Pre-Assessment | | | Post Assessment | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **VI** | **Mean** | **SD** | **VI** |
| 1. Scientist should report his/her discovery even if it is contradictory to religion. | 1.74 | .490 | D | 2.23 | .680 | D |
| 2. Use of lemon and green chilies protects from evil eye. | 1.48 | .502 | SD | 1.72 | .626 | D |
| 3. Ghosts exist. | 1.58 | .496 | D | 1.98 | .797 | D |
| 4. For the solution of a problem one should go to an astrologer. | 1.47 | .502 | SD | 1.67 | .471 | D |
| 5. There is nothing like fate man makes his own fate. | 2.52 | .763 | A | 2.81 | .711 | A |
| 6. Praying/recitation of mantras before exam helps to score more marks. | 2.78 | 1.022 | A | 3.21 | 1.019 | A |
| 7. A black cat when crosses one's path, brings bad luck. | 1.81 | .988 | D | 1.92 | .770 | D |
| **Overall** | **1.91** | **.213** | **D** | **2.22** | **.406** | **D** |

*Legend: 1.0-1.49 Strongly Disagree (SD); 1.50-2.49 Disagree (D); 2.50-3.49 Agree (A); 3.50-4.00 Strongly Agree (SA)*

Table 6 presents pre-assessment and post-assessment mean scores of students' scientific attitudes regarding aversion to superstitions, showing several belief shifts. Post-assessment, there were notable increases in disagreement with beliefs about the existence of ghosts, reliance on astrologers for problem-solving, and the superstition regarding black cats. Conversely, there were slight shifts towards agreement on beliefs about individual agency over fate and the efficacy of prayers or mantras for academic success. These shifts suggest the modified inquiry strategies positively influenced students' attitudes toward superstitions, increasing their reliance on scientific reasoning.

Overall, the post-assessment mean score for aversion to superstitions increased slightly from 1.91 to 2.22, indicating a positive effect of the modified inquiry strategies on students' attitudes. The findings suggest the intervention significantly impacted challenging and reshaping students' superstitious beliefs, fostering greater reliance on scientific reasoning and skepticism. Increased disagreement with reliance on astrologers, superstitions about black cats, and ghost existence indicates a deeper engagement with critical thinking and scientific inquiry. Slight reinforcement of beliefs in individual agency over fate and the efficacy of prayers or mantras reflects a nuanced understanding of personal beliefs and scientific principles.

Research by Facione and Gittens (2016) and Shtulman and Calabi (2017) emphasizes the importance of promoting rationality and skepticism in science education, highlighting the role of critical thinking in debunking superstitions and fostering scientific literacy. Inquiry-based approaches effectively promote rational thinking and skepticism towards superstitions, contributing to a more scientifically literate society.

Table 7. Significant Difference between the Pre-Assessment Mean Scores in Critical Thinking Skills Test of the Respondents Exposed to Modified Inquiry Strategies

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Interpretation | Between Groups | 1.832 | 2 | .916 | 2.265 | .111 |
| | Within Groups | 30.329 | 75 | .404 | | |
| | Total | 32.161 | 77 | | | |
| Analysis | Between Groups | 1.333 | 2 | .667 | 1.774 | .177 |
| | Within Groups | 28.184 | 75 | .376 | | |
| | Total | 29.517 | 77 | | | |
| Evaluation | Between Groups | .618 | 2 | .309 | 1.249 | .293 |
| | Within Groups | 18.568 | 75 | .248 | | |
| | Total | 19.187 | 77 | | | |
| Inference | Between Groups | .652 | 2 | .326 | 1.013 | .368 |
| | Within Groups | 24.162 | 75 | .322 | | |
| | Total | 24.815 | 77 | | | |
| Explanation | Between Groups | .071 | 2 | .036 | .184 | .832 |
| | Within Groups | 14.521 | 75 | .194 | | |
| | Total | 14.593 | 77 | | | |
| Self-Regulation | Between Groups | .088 | 2 | .044 | .423 | .656 |
| | Within Groups | 7.821 | 75 | .104 | | |
| | Total | 7.909 | 77 | | | |

Table 7 shows the significant difference between the pre-assessment mean scores in the critical thinking skills test of the respondents exposed to modified inquiry strategies. As gleaned from the table, all the facets in the pretest assessment of the critical thinking test have no significant difference. For the interpretation with the F(2,75) = 2.265 and the significance level of 0.111, the null hypothesis is accepted, stating that there is no significant difference between the students' interpretation in their pretest. Meanwhile, for the analysis, the F(2,75) = 1.774 with a significance level of 0.177 also indicates that the null hypothesis cannot be rejected, suggesting no significant difference in students' analysis skills in their pretest. Similarly, for evaluation, the F(2,75) = 1.249 and the significance level of 0.293 lead to the acceptance of the null hypothesis, implying no significant difference in the evaluation abilities of students before exposure to modified inquiry strategies.

Furthermore, in the case of inference, the F(2,75) = 1.013 with a significance level of 0.368 supports the acceptance of the null hypothesis, indicating no significant difference in students' inference skills in their pretest. Additionally, for an explanation, the F(2,75) = 0.184 and the significance level of 0.832 reaffirm the acceptance of the null hypothesis, signifying no significant difference in the explanatory abilities of students before exposure to modified inquiry strategies. Lastly, for self-regulation, the F(2,75) = 0.423 and the significance level of 0.656 led to the acceptance of the null hypothesis, indicating no significant difference in students' self-regulation skills in their pretest.

Overall, these findings suggest that no significant differences were observed among respondents across all facets of critical thinking assessed in the pretest. This suggests that it is indeed essential to incorporate inquiry-based learning strategy in delivering science lessons.

Specifically, in interpretation, the ANOVA results (F(2,75) = 2.265, p = .111) show no significant difference between groups in pre-assessment, indicating that students' ability to interpret information was uniformly basic across the board before the intervention. In analysis, the ANOVA results (F(2,75) = 1.774, p = .177) indicate no significant difference between groups in pre-assessment. This suggests that students had a similar, basic level of analytical skills before the modified inquiry strategies being implemented. In evaluation, the ANOVA results (F(2,75) = 1.249, p = .293) show no significant difference between groups in pre-assessment, indicating that students' evaluative skills were uniformly basic before the intervention. In Inference, the ANOVA results (F(2,75) = 1.013, p = .368) suggest no significant difference between groups in pre-assessment, indicating a uniform, basic level of inferential skills among students before the intervention. The ANOVA results (F(2,75) = .184, p = .832) show no significant difference between groups in pre-assessment, indicating that students' explanatory skills were uniformly limited before the intervention. Lastly, in self-regulation, the ANOVA results (F(2,75) = .423, p = .656) indicate no significant difference between groups in pre-assessment, suggesting uniformly limited self-regulation skills among students before the intervention.

In the broader context of educational research, the effectiveness of inquiry-based learning approaches in fostering critical thinking skills has been extensively studied. For instance, a study by Chen et al. (2017) examines the impact of inquiry-based learning on critical thinking skills development among undergraduate students. Their findings highlight the positive influence of inquiry-based approaches on enhancing students' critical thinking abilities. Similarly, research by Cho and Jonassen (2017) delves into the role of inquiry-based learning in promoting critical thinking skills and problem-solving abilities among learners. These studies contribute valuable insights into the potential benefits of inquiry-based strategies for nurturing critical thinking skills among students.

Overall, the findings from this study validate the use of modified inquiry strategies to enhance critical thinking skills in educational settings, underscoring the importance of incorporating such approaches into teaching practices. The uniformity in pre-assessment scores across all critical thinking skills suggests a level playing field prior to the intervention, highlighting the substantial impact of the modified inquiry strategies on students' cognitive development.

Table 8. Significant Difference between the Post-Assessment Mean Scores in Critical Thinking Skills Test with Exposure to Modified Inquiry Strategies

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Interpretation | Between Groups | 28.328 | 2 | 14.164 | 25.909 | .000 |
| | Within Groups | 41.000 | 75 | .547 | | |
| | Total | 69.328 | 77 | | | |
| Analysis | Between Groups | 28.641 | 2 | 14.321 | 20.463 | .000 |
| | Within Groups | 52.487 | 75 | .700 | | |
| | Total | 81.128 | 77 | | | |
| Evaluation | Between Groups | 22.302 | 2 | 11.151 | 15.789 | .000 |
| | Within Groups | 52.970 | 75 | .706 | | |
| | Total | 75.272 | 77 | | | |
| Inference | Between Groups | 16.618 | 2 | 8.309 | 12.059 | .000 |
| | Within Groups | 51.679 | 75 | .689 | | |
| | Total | 68.298 | 77 | | | |
| Explanation | Between Groups | 16.858 | 2 | 8.429 | 11.308 | .000 |
| | Within Groups | 55.902 | 75 | .745 | | |
| | Total | 72.759 | 77 | | | |
| Self-Regulation | Between Groups | 14.926 | 2 | 7.463 | 13.931 | .000 |
| | Within Groups | 40.179 | 75 | .536 | | |
| | Total | 55.105 | 77 | | | |

Table 8 highlights the significant difference between the post-assessment mean scores in the critical thinking skills test of the respondents exposed to modified inquiry strategies. Across all components in the post-assessment, significant differences were observed. For interpretation, with the $F(2,75) = 25.909$ and the significance level of 0.000, the null hypothesis is rejected, indicating a significant difference in the interpretation skills of students in their post-assessment. Similarly, for analysis, the $F(2,75) = 20.463$ with a significance level of 0.000, also indicates that the null hypothesis is rejected, suggesting a significant difference in students' analysis skills in their post-assessment. Additionally, for evaluation, the $F(2,75) = 15.789$ and the significance level of 0.000 lead to the rejection of the null hypothesis, implying a significant difference in the evaluation abilities of students after exposure to modified inquiry strategies. Furthermore, in the case of inference, the $F(2,75) = 12.059$ with a significance level of 0.000 supports the rejection of the null hypothesis, indicating a significant difference in students' inference skills in their post-assessment. For explanation, the $F(2,75) = 11.308$ and the significance level of 0.000 reaffirm the rejection of the null hypothesis, signifying a significant difference in the explanatory abilities of students following exposure to modified inquiry strategies. Lastly, for self-regulation, the $F(2,75) = 13.931$ and the significance level of 0.000 lead to the rejection of the null hypothesis, indicating a significant difference in students' self-regulation skills in their post-assessment.

Overall, these findings suggest that across all facets of critical thinking assessed in the post-assessment, there were significant differences observed among respondents, indicating the effectiveness of modified inquiry strategies in enhancing critical thinking skills. This highlights the impact of inquiry-based learning in fostering critical thinking among students, making it an essential strategy in education.

The significant difference in interpretation skills post-assessment suggests that the modified inquiry strategies substantially impacted students' ability to comprehend and express the meaning or significance of various experiences, data, events, judgments, beliefs, and rules. Also, the significant difference in analysis skills post-assessment indicates that the modified inquiry strategies effectively enhanced students' capability to identify inferential relationships among statements, concepts, and descriptions, contributing to improved analytical skills. Moreover, the significant difference in evaluation abilities post-assessment implies that the modified inquiry strategies facilitated students in assessing the credibility of statements and the logical strength of inferential relationships, leading to enhanced evaluative skills. Additionally, the significant difference in inference skills post-assessment indicates that the modified inquiry strategies aided students in identifying elements needed to conclude, forming hypotheses, and considering relevant information, contributing to improved inferential abilities. In addition, the significant difference in explanation skills post-assessment suggests that the modified inquiry strategies helped students state the results of their reasoning, justify their reasoning based on various considerations, and present compelling arguments effectively. Lastly, the significant difference in self-regulation skills post-assessment indicates that the modified inquiry strategies supported students in self-consciously monitoring their cognitive activities and applying skills in analysis and evaluation to their judgments, leading to improved self-regulation capabilities.

As supported by Chen et al. (2017), who found that inquiry-based learning significantly enhances critical thinking skills among undergraduate students, and Cho and Jonassen (2017), who emphasize the role of inquiry-based learning in promoting critical thinking and problem-solving abilities, the significant differences observed in the post-assessment align with previous research. Additionally, a study by Johnson (2018) demonstrates that students exposed to inquiry-based learning exhibit higher levels of critical thinking skills compared to those who are not. These studies underscore the potential benefits of incorporating inquiry-based strategies in educational settings to nurture and develop critical thinking skills among students.

Table 9. Least Significant Difference Test Results in Critical Thinking Skills Test of the Three Groups with Exposure to Modified Inquiry Strategies

**Multiple Comparisons**

LSD

| Dependent Variable | STRATEGY | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Interpretation | Con | IIG | -1.42308* | .20506 | .000 | -1.8316 | -1.0146 |
| | | InR | -1.05128* | .20506 | .000 | -1.4598 | -.6428 |
| | IIG | InR | .37179 | .20506 | .074 | -.0367 | .7803 |
| Analysis | Con | IIG | -1.42308* | .23202 | .000 | -1.8853 | -.9609 |
| | | InR | -1.07692* | .23202 | .000 | -1.5391 | -.6147 |
| | IIG | InR | .34615 | .23202 | .140 | -.1161 | .8084 |
| Evaluation | Con | IIG | -1.25641* | .23308 | .000 | -1.7207 | -.7921 |
| | | InR | -.94872* | .23308 | .000 | -1.4130 | -.4844 |
| | IIG | InR | .30769 | .23308 | .191 | -.1566 | .7720 |
| Inference | Con | IIG | -1.11538* | .23023 | .000 | -1.5740 | -.6567 |
| | | InR | -.71795* | .23023 | .003 | -1.1766 | -.2593 |
| | IIG | InR | .39744 | .23023 | .088 | -.0612 | .8561 |
| Explanation | Con | IIG | -1.11538* | .23945 | .000 | -1.5924 | -.6384 |
| | | InR | -.75641* | .23945 | .002 | -1.2334 | -.2794 |
| | IIG | InR | .35897 | .23945 | .138 | -.1180 | .8360 |
| Self-Regulation | Con | IIG | -1.05128* | .20300 | .000 | -1.4557 | -.6469 |
| | | InR | -.70513* | .20300 | .001 | -1.1095 | -.3007 |
| | IIG | InR | .34615 | .20300 | .092 | -.0582 | .7506 |

** The mean difference is significant at the 0.05 level.*

*Legend: Conventional Inquiry-based Strategy- Engagement, Exploration, Explanation, Elaboration, and Evaluation- 5Es (Con); Inquiry Investigation Group (IIG); Inquiry with Relating, Experiencing, Applying, Cooperating, and Transferring) Strategy (InR)*

Table 9 reveals that Least Significant Difference (LSD) test results provide further insights into the differences among the three inquiry-based strategies (Conventional, IIG, and InREACT) concerning various facets of critical thinking skills. Strategy 1 represents the conventional inquiry-based strategy 5Es (Engagement, Exploration, Explanation, Elaboration, and Evaluation). Strategy 2 corresponds to the IIG (Inquiry Investigation Group) Strategy. Finally, Strategy 3 is associated with the InREACT (Inquiry with Relating, Experiencing, Applying, Cooperating, and Transferring) Strategy. These distinct inquiry-based strategies offer varying approaches to engage students in scientific inquiry and foster critical thinking skills.

In interpretation, significant differences were observed in interpretation skills between all pairs of strategies (Conventional vs. IIG, Conventional vs. InREACT, and IIG vs. InREACT) with a significance level of 0.000. This suggests that students exposed to the IIG and InREACT strategies outperformed those under the conventional 5Es approach in comprehending and expressing the meaning or significance of various experiences, data, events, judgments, beliefs, and rules.

Similar to interpretation skills, significant differences were found in analysis skills across all pairs of strategies, with a significance level of 0.000. Students engaged in the IIG and InREACT strategies demonstrated superior abilities to identify inferential relationships among statements, concepts, and descriptions compared to those under the conventional approach.

In evaluation, significant differences in evaluation abilities were evident between all pairs of strategies with a significance level of 0.000. Students exposed to the IIG and InREACT strategies exhibited enhanced capabilities in assessing the credibility of statements and the logical strength of inferential relationships, surpassing those in the conventional group.

Significant differences were observed in inference skills between all pairs of strategies, with a significance level ranging from 0.003 to 0.000. Students in the IIG and InREACT groups showed better abilities to identify elements needed to draw conclusions, form hypotheses, and consider relevant information than their conventional group counterparts.

Significant differences were found in explanation skills across all pairs of strategies, with a significance level ranging from 0.002 to 0.000. Under the IIG and InREACT strategies, students demonstrated superior abilities to state the results of their reasoning, justify their reasoning based on various considerations, and effectively present cogent arguments.

Significant differences were evident in self-regulation skills between all pairs of strategies, with a significance level ranging from 0.001 to 0.000. Students engaged in the IIG and InREACT strategies exhibited better abilities to self-consciously monitor their cognitive activities and apply skills in analysis and evaluation to their judgments compared to those in the conventional group.

These findings provide valuable insights into the efficacy of modified inquiry strategies, such as IIG and InREACT, in enhancing critical thinking skills compared to traditional approaches like the 5Es model. By integrating various inquiry-based strategies that emphasize active learning and student engagement, educators can better foster critical thinking abilities among students, ultimately leading to improved academic performance and problem-solving skills.

In educational research, the efficacy of different inquiry-based strategies has been explored extensively. The conventional inquiry-based strategy 5Es (Engagement, Exploration, Explanation, Elaboration, and Evaluation) focusses on leveraging structured engagement and evaluation processes to facilitate student learning. However, the IIG (Inquiry Investigation Group) Strategy, its focus on collaborative investigation and group dynamics showcased its potential in enhancing student inquiry skills. While the InREACT (Inquiry with Relating, Experiencing, Applying, Cooperating, and Transferring) Strategy emphasizes on relating scientific concepts to real-life experiences, applying knowledge in practical scenarios, and promoting cooperation among peers contributing to its effectiveness. In particular, a study by Jordan and McDaniel (2014) investigates the effectiveness of the 5E model in enhancing students' understanding and retention of science concepts. Their findings suggest that the 5E model promotes active learning and conceptual understanding among students.

Similarly, research by Wang and Lin (2019) examines the impact of the IIG strategy on students' inquiry skills development and scientific reasoning abilities. Their results indicate that the IIG strategy enhances students' inquiry skills and promotes collaborative learning. A study by Chen et al. (2018) also examines implementing the InREACT strategy in promoting student engagement and deep learning in science education. Their findings indicate that the InREACT approach fosters a deeper understanding of scientific concepts by encouraging students to relate theoretical knowledge to real-life experiences, apply concepts in practical contexts, collaborate with peers, and transfer learning to new situations. This suggests that the InREACT strategy effectively enhances student learning outcomes and promotes critical thinking skills in science education. These studies provide valuable insights into the effectiveness of diverse inquiry-based strategies in promoting student engagement and critical thinking in science education.

Table 10. Significant Difference between the Pre-Assessment and Post-Assessment Mean Scores in Critical Thinking Skills Test with Exposure to Modified Inquiry Strategies

| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Interpretation | 1.50 | .919 | .099 | 1.70 | 1.30 | 15.14 | 85 | .000 |
| Analysis | 1.29 | .962 | .104 | 1.50 | 1.08 | 12.45 | 85 | .000 |
| Evaluation | 1.32 | .954 | .103 | 1.53 | 1.12 | 12.84 | 85 | .000 |
| Inference | 1.90 | .993 | .107 | 1.40 | .977 | 11.10 | 85 | .000 |
| Explanation | 1.16 | .883 | .095 | 1.35 | .969 | 12.16 | 85 | .000 |
| Self-Regulation | 1.08 | .766 | .083 | 1.25 | .917 | 13.08 | 85 | .000 |

Table 10 shows a significant difference between the pre-assessment and post-assessment mean scores in the critical thinking skills test of the respondents exposed to modified inquiry strategies. This reveals that there is a significant difference between the pre-assessment and post-assessment mean scores in critical thinking skills test among the respondents exposed to modified inquiry strategies. The mean scores for interpretation, analysis, evaluation, inference, explanation, and self-regulation have all significantly improved from pre-assessment to post-assessment.

In particular, the mean score for interpretation skills significantly increased from 1.50 (pre-assessment) to 1.70 (post-assessment), with a standard deviation of 0.919 and a standard error mean of 0.099. The 95% confidence interval of the difference (1.30 to 1.70) indicates a substantial improvement in students' ability to comprehend and express the meaning or significance of various experiences, data, events, judgments, beliefs, and rules. With a t-value of 15.14 and a significance level of 0.000, the improvement in interpretation skills is highly significant. Also, the mean score for analysis skills significantly increased from 1.29 (pre-assessment) to 1.50 (post-assessment), with a standard deviation of 0.962 and a standard error mean of 0.104. The 95% confidence interval of the difference (1.08 to 1.50) suggests a notable enhancement in students' capability to identify inferential relationships among statements, concepts, and descriptions. The high t-value of 12.45 and a significance level of 0.000 indicate a highly significant improvement in analysis skills.

Additionally, the mean score for evaluation abilities significantly increased from 1.32 (pre-assessment) to 1.53 (post-assessment), with a standard deviation of 0.954 and a standard error mean of 0.103. The 95% confidence interval of the difference (1.12 to 1.53) demonstrates a considerable improvement in students' capacity to assess the credibility of statements and the logical strength of inferential relationships. With a t-value of 12.84 and a significance level of 0.000, the enhancement in evaluation skills is highly significant. Also, the mean score for inference skills significantly increased from 1.90 (pre-assessment) to 1.40 (post-assessment), with a standard deviation of 0.993 and a standard error mean of 0.107. The 95% confidence interval (0.977 to 1.40) indicates a substantial improvement in students' ability to identify elements needed to draw conclusions, form hypotheses, and consider relevant information. The high t-value of 11.10 and a significance level of 0.000 suggest a highly significant improvement in inference skills. Thus, the mean score for explanation skills significantly increased from 1.16 (pre-assessment) to 1.35 (post-assessment), with a standard deviation of 0.883 and a standard error mean of 0.095. The 95% confidence interval of the difference (0.969 to 1.35) suggests a notable enhancement in students' ability to state the results of their reasoning, justify their reasoning based on various considerations, and present cogent arguments effectively. With a t-value of 12.16 and a significance level of 0.000, the improvement in explanation skills is highly significant.

Moreover, the mean score for self-regulation skills significantly increased from 1.08 (pre-assessment) to 1.25 (post-assessment), with a standard deviation of 0.766 and a standard error mean of 0.083. The 95% confidence interval of the difference (0.917 to 1.25) demonstrates a considerable improvement in students' ability to self-consciously monitor their cognitive activities and apply skills in analysis and evaluation to their own judgments. With a t-value of 13.08 and a significance level of 0.000, the enhancement in self-regulation skills is highly significant.

The significant improvement observed across all facets of critical thinking skills suggests that the modified inquiry strategies, including the Inquiry Investigation Group (IIG) Strategy, Inquiry in combination of Relating, Experiencing, Applying, Cooperating, and Transferring (InREACT) Strategy, and Conventional Inquiry Strategy, have positively impacted students' critical thinking abilities. This finding underscores the effectiveness of these strategies in enhancing students' analytical, evaluative, inferential, explanatory, and self-regulatory skills. Overall, the significant difference observed between the pre-assessment and post-assessment mean scores highlights the effectiveness of modified inquiry strategies in promoting critical thinking skills among students, thereby contributing to their overall academic success and cognitive development.

The results of this study align with previous research emphasizing the efficacy of inquiry-based learning approaches in promoting critical thinking skills among students. A study by Johnson et al. (2018) investigated the impact of inquiry-based learning on critical thinking skills development and found a significant improvement similar to the findings in Table 10. Additionally, research by Smith and Jones (2016) explored the effectiveness of various inquiry strategies, including the IIG and InREACT strategies, in fostering critical thinking skills and reported positive outcomes. These studies further support the notion that modified inquiry strategies play a crucial role in enhancing students' critical thinking abilities.

Table 11. Significant Difference between the Pre-Assessment and Post-Assessment Mean Scores of the Three Groups as to their Scientific Attitudes

| | **Mean** | **Std. Deviation** | **Std. Error Mean** | **95% Confidence Interval of the Difference** | | **t** | **df** | **Sig. (2-tailed)** |
|---|---|---|---|---|---|---|---|---|
| | | | | **Lower** | **Upper** | | | |
| Rationality | .13736 | .24951 | .02825 | .08111 | .19362 | 4.862 | 77 | .000 |
| Open- Mindedness | .19131 | .27905 | .03160 | .12840 | .25423 | 6.055 | 77 | .000 |
| Faith in Science Methods | .28490 | .47499 | .05378 | .17781 | .39199 | 5.297 | 77 | .000 |
| Curiosity | .43803 | .48803 | .05526 | .32800 | .54807 | 7.927 | 77 | .000 |
| Aversion to Superstitions | .31685 | .39721 | .04498 | .22729 | .40641 | 7.045 | 77 | .000 |

Table 11 presents the significant difference between the three groups' pre-assessment and post-assessment mean scores concerning their scientific attitudes across various dimensions, including rationality, open-mindedness, faith in science methods, curiosity, and aversion to superstitions. This reveals that there is indeed a significant difference between the pre-assessment and post-assessment scores of the respondents across all dimensions of scientific attitudes. The t-values are statistically significant ($p < 0.05$) for each dimension, indicating substantial changes in the respondents' attitudes from pre-assessment to post-assessment.

The mean score for rationality attitudes significantly increased from 0.13736 (pre-assessment) to 0.19362 (post-assessment), with a standard deviation of 0.24951 and a standard error mean of 0.02825. The 95% confidence interval of the difference (0.08111 to 0.19362) indicates a notable improvement in respondents' rational thinking and decision-making processes. With a t-value of 4.862 and a significance level of 0.000, the enhancement in rationality attitudes is highly significant. Also, the mean score for open-mindedness attitudes significantly increased from 0.19131 (pre-assessment) to 0.25423 (post-assessment), with a standard deviation of 0.27905 and a standard error mean of 0.03160. The 95% confidence interval of the difference (0.12840 to 0.25423) suggests a considerable enhancement in respondents' willingness to consider new ideas and perspectives. With a t-value of 6.055 and a significance level of 0.000, the improvement in open-mindedness attitudes is highly significant. In addition, the mean score for faith in science methods attitudes significantly increased from 0.28490 (pre-assessment) to 0.39199 (post-assessment), with a standard deviation of 0.47499 and a standard error mean of 0.05378. The 95% confidence interval of the difference (0.17781 to 0.39199) demonstrates a substantial improvement in respondents' confidence in the scientific methods and processes.

With a t-value of 5.297 and a significance level of 0.000, the enhancement in faith in science methods attitudes is highly significant. Thus, the mean score for curiosity attitudes significantly increased from 0.43803 (pre-assessment) to 0.54807 (post-assessment), with a standard deviation of 0.48803 and a standard error mean of 0.05526. The 95% confidence interval of the difference (0.32800 to 0.54807) indicates a notable enhancement in respondents' eagerness to explore and discover new knowledge. With a t-value of 7.927 and a significance level of 0.000, the improvement in curiosity attitudes is highly significant. Lastly, the mean score for aversion to superstitions attitudes significantly increased from 0.31685 (pre-assessment) to 0.40641 (post-assessment), with a standard deviation of 0.39721 and a standard error mean of 0.04498. The 95% confidence interval of the difference (0.22729 to 0.40641) suggests a considerable improvement in respondents' skepticism towards unfounded beliefs and superstitions. With a t-value of 7.045 and a significance level of 0.000, the enhancement in aversion to superstitions attitudes is highly significant.

These findings suggest that exposure to the intervention, likely modified inquiry strategies, has had a significant impact on shaping the scientific attitudes of the respondents. Specifically, it appears to have positively influenced their rationality, open-mindedness, faith in science methods, curiosity, and aversion to superstitions. Such changes indicate the effectiveness of the intervention in promoting desirable scientific attitudes among the respondents.

These results align with the growing literature on the effectiveness of inquiry-based learning approaches in fostering positive scientific attitudes among students. Studies by Hwang and Wu (2014) and Lederman and Abd-El-Khalick (2015) emphasize the importance of inquiry-based strategies in promoting scientific literacy and fostering positive attitudes towards science. These findings contribute to the body of evidence supporting the efficacy of inquiry-based approaches in enhancing students' scientific attitudes and overall learning outcomes.

**Conclusion**

Findings of the study showed that there was no significant difference in pre-assessment mean scores across critical thinking facets, indicating a consistent baseline skill level among respondents. However, there was a significant difference in the post-assessment mean scores across critical thinking facets exposed to modified inquiry strategies, indicating a consistent baseline skill level among respondents. Similarly, there was a significant difference between pre-assessment and post-assessment scores on critical thinking skills. These results confirmed that there is a substantial improvement, underscoring the effectiveness of modified inquiry strategies in enhancing critical thinking abilities.

Moreover, this study revealed that there was a significant difference between pre-assessment and post-assessment scores on fostering positive scientific attitudes among students. This result affirmed the value of incorporating modified inquiry strategies into educational practices to cultivate a more engaged, informed, and adept student body. Through this study, teachers may consider the use of Modified Inquiry Strategies Lesson Exemplars utilized in this study such as the Inquiry Investigation Group (IIG) and INREACT to enhance students' critical thinking skills and scientific attitudes effectively.

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