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Enhancing the Development of Students' Critical Thinking and Scientific Reasoning Skills Through the Implementation of the "5E Instructional Model" in the Process of Learning Sciences: Case of a Lebanese Private High School

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ABSTRACT

The cultivation of critical thinking skills is imperative for individuals, necessitating the integration of daily critical thinking strategies within educational settings. This research aims to investigate the transformative impact of the 5-E Instructional Model on the development of critical thinking skills among elementary learners. The study specifically focuses on the adoption and implementation of the five phases of the 5-E model during science classes in the elementary division of a private school. Employing a comprehensive approach, the study utilized both descriptive quantitative and qualitative methodologies to address specific research questions. The participant pool comprised 60 individuals, with 20 teachers and 40 students. Data collection occurred between January and May 2018, employing mixed-mode questionnaires. The collected data were analyzed using SPSS. The results unequivocally demonstrated a positive impact of the 5-E Instructional Model on enhancing critical thinking skills among elementary learners at a private school. Notably, the study revealed a statistically significant relationship between the strategies implemented by science teachers during their classes and students' achievements in the science subject.

الكلمات المفتاحية:
التحصيل الأكاديمي
مهارات التفكير النقدي
الممارسات التعليمية
نموذج التعليم 5-***E***
نماذج التعلم
تعليم العلوم
التفكير العلمي

ملخص

إن تنمية مهارات التفكير النقدي أمر ضروري للأفراد، مما يستلزم دمج استراتيجيات التفكير النقدي اليومية ضمن البيئات التعليمية. يهدف هذا البحث إلى التحقيق في التأثير التحويلي لنموذج 5−E التعليمي على تنمية مهارات التفكير النقدي بين المتعلمين في المرحلة الابتدائية في دروس العلوم في القسم الابتدائي في مدرسة خاصة. تم استخدام المنهج الوصفي (الكمي والنوعي). ضمت مجموعة المشاركين 60 فردًا، مع 20 مدرسًا و40 طالبًا. جُمِعت البيانات بين يناير ومايو 2018، باستخدام استبيانات مختلطة. وحُلِّلت باستخدام برنامج SPSS. أظهرت النتائج بشكل لا لبس فيه تأثيرًا إيجابيًا لنموذج 5−E التعليمي على تعزيز مهارات التفكير النقدي بين المتعلمين في المرحلة الابتدائية في مدرسة خاصة. كما كشفت الدراسة عن وجود علاقة ذات دلالة إحصائية بين الاستراتيجيات التي يطبقها معلمو العلوم أثناء حصصهم الدراسية وتحصيل الطلبة في مادة العلوم.

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1 Introduction

Teaching and learning, centered on critical thinking pedagogies, stand as fundamental goals in education (Paul & Elder, 2020). The effective implementation of critical thinking continues to gain prominence. Research by Lai, Lin, and Chang (2019) reveals that fostering critical thinking in science classes not only enhances students' understanding of the scientific process but also encourages them to adopt a more experimental and questioning approach to various scientific aspects. Educators worldwide are actively shaping innovative learning models to better equip learners for the challenges of the 21st Century.

According to Lai, Lin, and Chang(2019), three factors drive the growing interest in critical thinking development. First, many learners lack a profound understanding of the subjects they study, as evidenced by their inability to apply acquired knowledge to real-world situations. This deficiency is attributed to superficial teaching methods that fail to engage students in deep and critical thinking about the content.

Secondly, the modern world demands increased cognitive skills, with future jobs requiring adaptability and sophisticated learning capabilities (Dede, 2018). Lastly, business leaders express concerns about the perceived inability of school graduates to apply critical thinking skills in practical scenarios such as effective communication, mathematical proficiency, and on-the-job learning (World Economic Forum, 2020).

Critical thinking involves a synthesis of background knowledge, the application of basic processes, and an awareness of the thinking process itself. Most crucially, it entails the cultivation of attitudes and dispositions, including open-mindedness, evidence-based decision-making, and healthy skepticism. This study aims to explore the impact of the 5-E Instructional Model on enhancing critical thinking skills in elementary learners, contributing valuable insights to the ongoing discourse on effective educational practices.

1.1 Problem of the Study

The Science Department at Al Makassed Khalid Bin Al-Walid School aims to provide high-quality education to students, preparing them to reach their full potential and contribute to personal, societal, regional, and global development. However, the science department coordinator emphasized the need for higher quality, increased effectiveness, improved efficiency, and enhanced equity in the science education system. As a result, the coordinator implemented strategies to develop students' critical thinking and scientific reasoning skills, preparing them to face real-life situations in the twenty-first century. The implemented strategies focus on making students the center of the learning process, with teachers acting as facilitators, empowering schools, and strengthening the science education system. Cooperative Learning and Problem-Based Learning are key strategies, involving small groups working together to solve scientific problems. The science coordination system acknowledges the vital role of science teachers in implementing these strategies to enhance higher-order thinking and cognitive abilities among learners. Following an analysis of students' academic achievements in the 2016-2017 term tests, which showed a low success rate in the domain measuring scientific reasoning and critical thinking skills, the science department decided to implement new strategies in 2018 to enhance students' critical thinking. These new strategies aim to support effective, efficient, and equitable education and prepare learners to handle complex real-life problems.

1.2 Purpose of the Study

Building upon the aforementioned context, this study aims to investigate the impact of implementing new strategies and practices designed to enhance the development of students' critical thinking and scientific reasoning within the science curriculum.

1.3 Research Questions

1. To what extent does the 5-E Instructional Model for elementary school science (Bybee, 2006) influence students' critical thinking and scientific reasoning skills? This influence will be

assessed through the dimensions of (1) improvement in academic achievements in the science subject and (2) the ability to navigate complex real-life situations.

2. What is the role of science teachers in shaping the critical thinking skills of young learners?

1.4 Significance of the Study

Critical thinking is not just an academic skill; it is a life skill crucial for tackling real-world challenges. This study dives into the impact of infusing critical thinking into science classrooms and explores whether it translates into improved academic performance in the subject. It is a call for educators, from early childhood to high school, to ditch old-school teaching methods and embrace newer, more engaging approaches that foster higher-order critical thinking skills.

Since 2017, the science department at this private school has been shaking things up. They have been introducing new strategies to nurture 21st-century skills and foster an interactive learning community. At the heart of these changes is the 5-E Instructional Model, a key player in implementing practices that boost critical thinking skills. To ensure its effectiveness, the model underwent an eight-week trial in a grade-six section, complete with carefully selected assessments and instructional tools.

The study of this methodology is not just about academic scores; it delves into student performance and critical thinking abilities. Through ongoing evaluations mirroring real-life situations, it aims to gauge the impact of the 5-E Instructional Model on academic success in science.

The proposed case study has tangible benefits in relation to better academic performance, equipping students with 21st-century skills, and boosting their innovative thinking. It is a contribution to the ongoing conversation about revamping teaching methods to better suit the needs of today's learners.

Consequently, this study advocates for a pedagogical shift among educators, urging them for a transition from traditional lecture-based approaches to interactive teaching methods that prioritize skill development over content delivery. The anticipated outcomes of this proposed case study include improvements in students' academic performance, the cultivation of learners equipped with 21st-century skills, and the enhancement of their capabilities for increased innovation and creativity.

1.5 Literature Review

Critical thinking and its attributes have garnered considerable attention from researchers, educators, and authors worldwide due to their perceived significance in the learning process. The global interest in implementing critical thinking in education underscores its importance. According to Siegel (1990), a critical thinker is one who is appropriately moved by reason, embodying impartiality, consistency, and non-arbitrariness. Wade (1995) identified eight main characteristics of critical thinking, including asking questions, defining problems, examining evidence, analyzing and interpreting, avoiding emotional reasoning, avoiding simplification, considering other interpretations, and tolerating ambiguity.

Dealing with ambiguity is emphasized by Strohm & Baukus (1995) as an essential part of critical thinking. Jones and Ratcliff (1993) highlighted metacognition—thinking about one's own thinking—as a basic element. Beyer outlines essential aspects of critical thinking, including dispositions (skepticism, open-mindedness, and respect for evidence), criteria, argumentation, reasoning, point of view consideration, and procedures for applying criteria.

Paul (1995) introduced key questions critical thinkers ask that include addressing the purpose of the study, defining problems, examining perspectives, shaping investigations, acknowledging assumptions, considering information sources, interpreting data, drawing conclusions, and evaluating implications. Carroll (2005) asserted that critical thinkers make better problem solvers and decision-makers, embodying open-mindedness and skepticism.

Ennis (1987) emphasized dispositions and abilities associated with critical thinking, focusing on reflective skepticism and reasoned thinking. Ferrett (1997), Ennis (1996), Elder & Paul (1996a), Beyer (1985), and Costa (1985) identified sequential steps for critical thinkers, including posing relevant questions, evaluating statements, searching for diverse sources, demonstrating curiosity,

shaping criteria, discovering analogies, reexamining perceptions, listening effectively, avoiding premature conclusions, looking for supporting evidence, disregarding irrelevant data, and viewing critical thinking as self-evaluation and a lifelong process. These multifaceted characteristics collectively define the essence of critical thinking.

The Role of Science Teachers as Educational Facilitators

The role of science teachers, often seen as educational facilitators, involves employing methods united by a common objective encouraging students to utilize their intellectual abilities actively. Critical thinking, highlighted by educators and policymakers, is central to this pedagogical approach (Butler qtd. in Liu, Frankel & Roohr 1). Scrivener emphasized that the teacher's primary role is to facilitate learning, involving students by enabling them to work at their own pace and encouraging active participation (Scrivener 18, 19).

Broughton underscored the importance of communicative language learning, asserting that students are most motivated when engaged in truly communicative practices (Broughton 47). Here, the students take center stage as the most active participants in the learning process. The teacher's role is transformed into that of an encourager and facilitator, fostering exploration and making learning interesting to develop critical thinking abilities in young learners.

Teachers must recognize that fostering critical thinking requires a different role—one of facilitation rather than traditional explanation. Acting as facilitators, educators encourage discussion, engage students in the learning process, and convey the understanding that critical thinking does not always yield a single right answer but may lead to more questions or diverse evaluations of a topic (Halx & Reybold, 2005; Arend, 2009).

The teacher's facilitator role extends to encouraging peer review processes, even among younger students, fostering appropriate responses to conflicting evaluations and opinions (Henderson-Hurley & Hurley, 2013; Tsai et al., 2013). Teachers demonstrate their role by implementing interactive activities aligned with Bloom's Taxonomy of higher-order thinking, such as experimental procedures and investigating critical questions (Smith & Szymanski, 2013). Another effective strategy involves using wikis in education, allowing students to create or analyze content collaboratively (Snodgrass, 2011).

Kokkidou's findings suggest that challenging students to think critically yields benefits for both students and educators, enhancing creativity, performance, and literacy within the realm of music (Kokkidou, 2013). Arend (2009) supported the use of online discussion boards and interactive hands-on activities to develop and enhance critical thinking while providing students with a deeper understanding of class content. In summary, the teacher's role as a facilitator is pivotal in cultivating critical thinking skills and fostering an interactive and engaging learning environment.

Traditional Teaching

Traditional teaching, identified as "teacher-dominated interaction" by Broughton and colleagues, is characterized by a teacher-centered approach. In this conventional educational model, students are expected to learn passively through recitation and memorization, embodying the old-fashioned way of teaching. The focus is on the teacher imparting knowledge, with students playing the role of receivers.

In traditional teaching, students recite and memorize assignments and assessments such as written tests or oral examinations are conducted at the end of modules through a process known as the Assignment Study Recitation Test. This method ensures that students are rewarded for their efforts, class periods are used efficiently, and clear rules are established to manage student behavior. The teacher acts as the primary communicator of knowledge and enforcer of behavioral standards.

The Role of Traditional Teachers in Traditional Teaching

In the traditional teaching model, the teacher is likened to a pitcher, pouring knowledge into empty cups, symbolizing the passive role of learners as mere receivers (Scrivener 17). Richards noted that, traditionally, learning was perceived as under the control of the teacher, placing the responsibility for teaching and learning predominantly on the teacher (Richards 4).

The prevailing attitude in traditional teaching assumes that students, merely by being present in class and attentively listening to the teacher, will acquire knowledge. Despite potential

disadvantages, Scrivener highlighted the widespread use of this method globally, particularly in certain cultures (Scrivener 16, 38). The traditional teaching approach persists, relying on a teacher-centric model where learners are expected to absorb knowledge through passive reception.

Modern Teaching

Modern teaching is characterized by a student-centered approach, emphasizing active involvement and exploration. According to Jim Scrivener, the teacher's primary role is to facilitate learning by enabling students to work at their own pace, encouraging participation, and fostering interactions (Scrivener 18, 19). Broughton emphasized that language students are best motivated by communicative practices that align with the language's context, with the teacher's skills guiding them toward fuller language competence (Broughton 47).

In this student-centric model, learners are considered the most active participants in the learning process. The teacher's role is not to simply to explain but to inspire and assist students in exploring and making the learning experience engaging.

The Role of Modern Teachers in Modern Teaching

Modern teaching adopts a student-centered approach where the teacher serves as a facilitator, emphasizing active student involvement. Jim Scrivener emphasizes the teacher's role in enabling students to work at their own pace, encouraging participation and interaction (Scrivener 18, 19). Broughton supported this, noting that language students are motivated by communicative practices that enhance language competence (Broughton 47). In modern teaching, learners are considered the most active participants.

To prepare students for the 21st century, modern teaching shifts focus from knowledge to communicative competence (Richards 8). Ronald V. White outlines principles, prioritizing speech, connected text, and an oral methodology (White 11). Modern methods prioritize experiments and scientific debates over memorization, emphasizing skill development rather than memory testing. Tasks are designed to improve skills, with an emphasis on feedback, graded difficulty, and step-by-step guidance (Scrivener 170-173). Collaborative learning and comparing answers enhance motivation (Zemenová).

In science education, modern teaching involves students in scientific investigations, encouraging active participation, elicitations, and understanding checks. Various interactive methods, including 'guided discovery' and the Test-Teach-Test method, are recommended for effective learning (Scrivener 268, Zemenová). Modern teaching strategies aim to motivate learners, make lessons interesting, and facilitate skill development, aligning with real-life situations and ensuring activities are well-targeted.

What Is The 5-E Inquiry Model?

Figure 2. *The 5 E Inquiry Model*

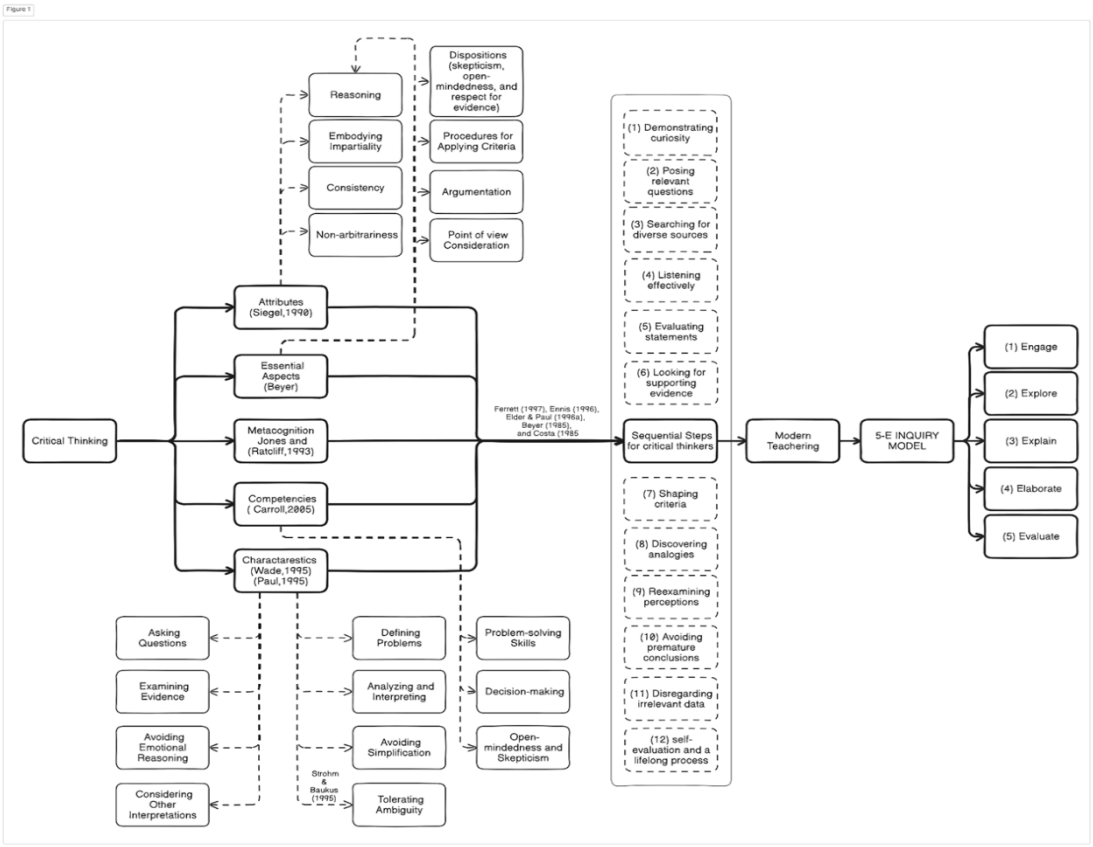

Figure 2. *Conceptualization of the study: Critical Thinking Framework*

The 5-E Instructional Model, developed as part of the Biological Curriculum Study for Elementary School Science by Bybee in 2006, comprises five key phases:

1. Engage: Teachers aim to generate interest, and curiosity, and elicit responses, stimulating students' prior knowledge.
2. Explore: Students are encouraged to collaborate, listen, observe, and ask questions, fostering a need-to-know environment.
3. Explain: Teachers guide students to articulate concepts, request justifications and evidence, clarify explanations, and assess comprehension.
4. Elaborate: At this stage, students apply new skills, pose questions, propose solutions, draw conclusions, record observations, and assess their peers' understanding.
5. Evaluate: Teachers observe students applying new concepts and skills, pose open-ended questions, and assess knowledge and skills. Bybee (2006) asserts that the 5-E Model is a crucial strategy for enhancing students' reasoning and critical thinking skills in science lessons.

2 Methodology

2.1 Research Design and Sample

This study is classified as both descriptive quantitative and qualitative. It involves the analysis of data collected through questionnaires and assessments, utilizing Statistical Package for the Social Sciences (SPSS) software, specifically version 23. Participants were generally measured once to study the association or relationship between the best practices and strategies in science education (considered as the independent variable) and the development of students' critical thinking and scientific reasoning. This development is reflected in two main dimensions: (1) improvement of academic performance and (2) ability to deal with complex real-life situations, serving as the dependent variables.

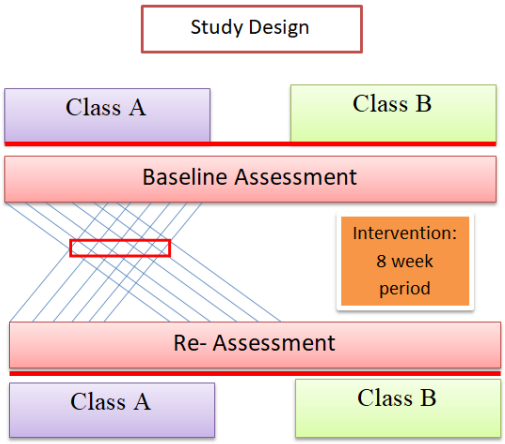

Figure 3. *The Study Design*

The researchers collected data from the population of teachers and sixth-grade students in a Lebanese private school from November 6, 2018, to May 20, 2019. The choice of this population was made to gain clear insights into the performance and practices of science teachers in their respective classrooms at the school. Additionally, sixth-grade students from two sections were included in the study. One section served as the control group (Class A), where the researchers applied traditional strategies to deliver scientific concepts. In contrast, the other section (Class B) was the experimental group, where the researchers implemented new strategies, specifically the 5-E instructional model, aiming to enhance the development of critical thinking.

A total of sixty participants (20 science teachers and 40 students) took part in the study.

2.2 Data Collection Tools

In this study, the researcher utilized pre-tests and post-tests, both employing the same format and complexity. These tests covered four lessons (muscular system, endocrine system, digestive system, and nervous system) with a duration of 50 minutes each, focusing on scientific reasoning and critical thinking skills. Additionally, a questionnaire survey was administered to students after one month, consisting of two parts: a personal section (11 questions) and a technical section (20 questions). The latter measured critical thinking abilities.

For science teachers, a questionnaire survey was employed to assess the emphasis on critical thinking skills in teaching science. This questionnaire comprised a personal part (27 items) exploring the teacher's profile and a technical part (53 items) covering five domains: classroom setting, availability of science resources, teaching practices and strategies, monitoring students' performance, and assessing students' performance.

2.3 Implementation

The 5-E Instructional Model was implemented over 8 weeks in a sixth-grade section at a private school. The strategy comprised five key phases aimed at fostering critical thinking and scientific reasoning. In the engagement phase, activities such as the 'KWLH' chart and 'think-pair-share' were utilized to stimulate thinking and encourage class discussion. The exploration phase focused on cooperative work, active listening, questioning, and creating a curiosity-driven environment. The explanation phase emphasized students explaining concepts, seeking justifications, and clarifying based on scientific investigations. The elaboration phase involved activities like comparing, explaining, summarizing, and engaging in the devil's advocate exercise to defend reasoning against various perspectives. Finally, in the evaluation phase, students applied new concepts, answered open-ended questions, and underwent assessments to gauge knowledge and skills.

2.4 Data Analysis

The study employed various analyses, including:

1. Frequency Analysis:
   - Examined the percentage of gender distribution of participants.
   - Analyzed the percentage of correct and incorrect answers.
2. Descriptive Analysis:
   - Compared pre and post-test outcomes for Class A and Class B.
   - Evaluated the percentage differences in the Muscular, Digestive, Endocrine, and Nervous Systems.
3. Chi-Square Analysis:
   - Demonstrated differences between qualitative variables in Class A and B, with corresponding p-values.
4. T-Test Analysis:
   - Compared average grades between Class A and Class B.
5. Cronbach Alpha:
   - Assessed the reliability of the questionnaire, divided into nine sets.

3 Findings And Discussions

The table below presents a comparison between classes A and B at the baseline assessment, focusing on gender and correct answers. The chi-square test, with a degree of freedom of 1, was employed to detect significant differences. Results indicate no significant difference in gender distribution between classes A and B (p-value = 0.7). However, analyzing vital systems, the muscular system's second and fourth questions show significant differences ($p < 0.05$), while the endocrine system indicates no significant difference. In the digestive system, most questions exhibit significant differences ($p < 0.05$), while the nervous system shows no significant difference. The independent two-sample chi-square test reveals no difference in average grades between classes A and B (t-test = -0.73, p-value = 0.4 > 0.05), indicating no significant difference at the baseline assessment between the two classes.

Table 1. *Comparison between Class A and Class B at Baseline*

Variable		A%	B%	*df*	*H0*	$\chi 2$	P-value
Gender	Male	60	55			0.1	0.7
	Female	40	45				
Muscular system	Q1	5	30	1	3.84	4.32	0.03
	Q2	80	40			6.66	0.01
	Q3	80	70			0.5	0.46
	Q4	1	20			4.44	0.03
Endocrine system	Q5	50	20			3.95	0.04
	Q6	80	75			0.14	0.7
	Q7	10	30			2.5	0.14
	Q8	10	60			11	0.001
Digestive system	Q9	50	50			0.00	1
	Q10	60	20			6.66	0.01
	Q11	80	45			5.22	0.02
	Q12	20	25			0.14	0.7
Nervous system	Q13	55	95			8.5	0.003
	Q14	60	95			7.02	0.008
	Q15	50	70			1.66	0.19
	Q16	40	65			2.5	0.11
	Total grade			*df*	*H0*	t-test	P-value
Mean		9.44	10.12	38	[-1.89 — 1.89]	-0.73	0.4

The table (1) compares post-test achievements between classes A and B, revealing higher percentages of correct answers in the muscular, endocrine, digestive, and nervous systems for class B. Chi-square values exceeding 3.84 indicate significant differences in post-test achievements between the two sections. Section B's post-test average mean (17.14) surpasses section A's (10.31), indicating better achievements in class B following the 5-E instructional model implementation. With chi-square values above 3.84, a p-value of 0.00 (< 0.05), and a t-test of -9.54, there is a significant difference in post-test correct answer percentages between classes A and B. Key conclusion: Class B demonstrates superior post-test achievements compared to class A after eight weeks of implementing the 5-E instructional model.

Table 2. *Comparison between Class A Post-test and Class B Post-test*

Variable		A Post %	B Post %	*df*	*H0*	$\chi 2$	P-value
Gender	Male	60	55			0.1	0.7
	Female	40	45				
Muscular system	Q1	65	90			3.58	0.05
	Q2	50	85			5.58	0.01
	Q3	40	85			8.64	0.003
Endocrine system	Q4	30	60			3.63	0.05
	Q5	70	90			4.32	0.03
	Q6	45	100			15.17	0.00
	Q7	30	95			18.02	0.00
	Q8	70	95	1	3.84	4.32	0.03
Digestive system	Q9	80	100			4.44	0.03
	Q10	40	100			17.14	0.00
	Q11	20	40			1.9	0.1
	Q12	90	95			0.36	0.5
Nervous system	Q13	80	95			2.05	0.1
	Q14	50	100			13.33	0.00
	Q15	35	90			12.9	0.00
	Q16	5	40			7.02	0.008
Total grade				*df*	*H0*	t-test	P-value
Mean		10.31	17.14	38	[-1.44—1.44]	-9.54	0.00

Table (2) highlights the contrasting improvements in classes A and B. The control group (Class A) exhibits slight improvement in three questions and significant improvement in three out of sixteen. In contrast, Class B demonstrates significant improvement in ten questions, with the last three showing no change due to already high baseline scores. Overall, the intervention plan in Class B over eight weeks results in more significant improvements compared to Class A, indicating the success of the implemented strategy.

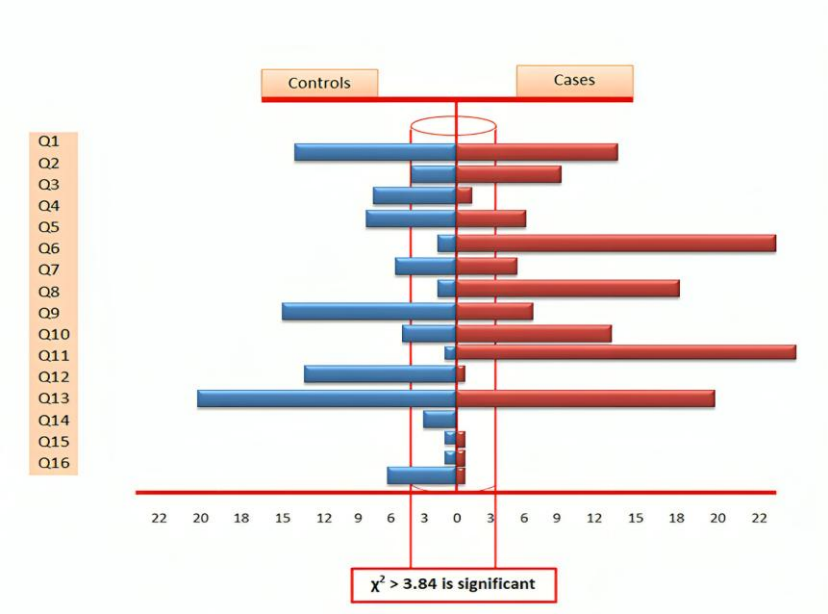

Figure 4. *Comparison between the improvement in Class A and Class B*

3.1 The Descriptive Analysis of the Science Teachers' Questionnaire

The descriptive analysis of the teachers' questionnaire, spanning eight domains, affirms the significant impact of science teachers on implementing strategies that enhance the development of critical thinking skills among young learners.

3.2 The Descriptive Analysis of the Students' Questionnaire

The end-of-year questionnaire comparing classes A and B revealed significant differences in personal and technical aspects. In the personal section, class B demonstrated a higher dependence on additional resources and a preference for internet usage, resulting in significant distinctions. While reading habits showed no significant differences, diverse interests in subjects exhibit notable variations between the two classes. Organizational involvement lacked significant differences, but class B showed increased participation in daily or weekly activities.

In the technical section, class B outperformed class A in multiple subquestions related to critical thinking situations, showcasing superior problem-solving abilities. Overall, the analysis suggested that students in class B demonstrated more effective critical thinking skills compared to their counterparts in class A.

3.3 Conclusion and Recommendations with Future Directives

The study affirms the positive impact of the 5-E Instructional Model on developing students' critical thinking skills and scientific reasoning in terms of academic achievements and the ability to handle complex real-life situations. Statistical analyses revealed a significant difference between the two student groups after implementing the 5-E Instructional Model in class B. Additionally, the research underscored the crucial role of science teachers in enhancing students' critical thinking skills across nine dimensions, including subject matter preparation, diverse teaching methods, and the integration of technology. The findings from the students' questionnaire indicated that class B students, one month after leaving the school, relied more on educational resources than their textbooks compared to class A. Furthermore, class B students exhibited better performance in dealing with complex real-life situations, as evidenced by higher percentages and significant differences in correct responses.

This research recommends the widespread adoption of the 5-E Instructional Model in all science classes to enhance critical thinking skills. Additionally, integrating technology through computer simulations is advised for virtual scientific investigations. Principals should encourage teacher engagement in science learning opportunities and promote collaboration. The inclusion of STEAM

activities across grade levels is recommended to develop diverse skills. Lastly, adopting a criterion-referenced test based on updated frameworks like Blooms and Marzano is suggested for a more comprehensive assessment. These recommendations aim to elevate science education. As a forward-looking suggestion, the researcher proposes a new avenue of research that aligns task words (action verbs) across both sciences and humanities. This approach aims to establish connections in cognitive thinking levels and mitigate discrepancies between subjects.

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