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ORIGINAL

The Role of Artificial Intelligence in Flipped Interactive Learning: Building a Generation of Critical Thinkers, Skilled Communicators, Effective Collaborators, and Creative Innovators

El papel de la inteligencia artificial en el aprendizaje interactivo invertido: creación de una generación de pensadores críticos, comunicadores hábiles, colaboradores eficaces e innovadores creativos

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ABSTRACT

This study examines the impact of targeted interventions on the development of 4C skills—critical thinking, communication, collaboration, and creativity—among students in control and experimental groups. Using pre-test and post-test designs, the results revealed significant improvements in the experimental group compared to the control group. The experimental group showed a mean increase of 9,3 points in post-test scores, while the control group exhibited a smaller increase of 3,4 points. Statistical analyses confirmed the homogeneity and normality of the data, with significant differences observed between pre-test and post-test scores in the experimental group ($p < 0,05$). These findings align with constructivist theories, including Vygotsky's *Zone of Proximal Development* and Bloom›s Taxonomy, emphasizing the role of active, student-centered learning in fostering higher-order thinking skills. The results also, highlighting the importance of integrating 21st-century skills into educational practices. The intervention's success may be attributed to its ability to balance the cognitive load and foster intrinsic motivation through engaging in relevant tasks. This study supports innovative teaching strategies and underscores their transformative potential in modern education.

Keywords: 4C Skills; Critical Thinking; Communication; Collaboration; Creativity; Artificial Intelligence.

RESUMEN

Este estudio examina el impacto de intervenciones específicas en el desarrollo de las habilidades 4C (pensamiento crítico, comunicación, colaboración y creatividad) entre estudiantes en grupos de control y experimentales. Utilizando diseños de pre-test y post-test, los resultados revelaron mejoras significativas en el grupo experimental en comparación con el grupo de control. El grupo experimental mostró un aumento medio de 9,3 puntos en las puntuaciones del post-test, mientras que el grupo de control exhibió un aumento menor de 3,4 puntos. Los análisis estadísticos confirmaron la homogeneidad y normalidad de los datos, con diferencias significativas observadas entre las puntuaciones del pre-test y del post-test en el grupo experimental ($p < 0,05$). Estos hallazgos se alinean con las teorías constructivistas, incluyendo la Zona de Desarrollo Próximo de Vygotsky y la Taxonomía de Bloom, enfatizando el papel del aprendizaje activo, centrado en el estudiante en el fomento de habilidades de pensamiento de orden superior. Los resultados también destacan la importancia de integrar las habilidades del siglo XXI en las prácticas educativas. El

éxito de la intervención puede atribuirse a su capacidad para equilibrar la carga cognitiva y fomentar la motivación intrínseca mediante la participación en tareas relevantes. Este estudio respalda las estrategias de enseñanza innovadoras y destaca su potencial transformador en la educación moderna.

Palabras clave: Habilidades 4C; Pensamiento Crítico; Comunicación; Colaboración; Creatividad; Inteligencia Artificial.

INTRODUCTION

In the era of the Fourth Industrial Revolution, the world of education faces significant challenges in preparing a generation that not only possesses academic knowledge but also masters the 21st-century skills known as the 4Cs: You will learn Critical Thinking, Communication, Collaboration, and Creativity. All these global skills prove vital in tackling the issues within the workforce and in life in the current fluidity of the digital age.[1] Education being a vital aspect in every society demands change due to advancements in technology affecting all sectors of life to offer the society the right talent that will fit in the economy. However, a large number of conventional approaches prevail in sociopolitical processes and are viewed as insufficient for developing these skills comprehensively.[2] Imposed learning processes that are familiar to most organizational development programs are run as a training process, where the trainer takes up most of the learning process, and the learners act merely as receivers of this information.[3] This model does not afford opportunities for students to generate original ideas or innovation, construct new meanings of the situation to think about it in novel ways or engage in collective cognition to solve the problem democratically. Thus, learners are not ready to solve real-life problems whether they are to solve them individually or in a group.[4]

The often-used model in the current education systems – where students sit in front of the teacher or professor who reads aloud and memorization– is ineffective in developing the environments that lead to meaningful, innovative, and effective learning. While students may memorize content throughout the day, they are seldom given a chance to solve problems that require the acquired knowledge. In addition, the notion of measurement, especially in many education systems today, has shifted from more general competency-based measurements to an over-reliance on content knowledge assessments that do not measure higher-order skills, including critical thinking, communication, collaboration, and creativity.[5] Such shortcomings point to the increasing imperativeness of enhancing more fluid, real-life, and student-engaged ways that are likely to work well in 21st-century learning environments than the fixed and conventional teacher-cantered model. Among the methods that have been developed and have floored, a classic approach capable of addressing these challenges is Flipped Interactive Learning. This approach thus turns around the conventional learning model through the use of digital solutions.[6]

Flipped Learning involves assigning pre-class material through teaching tools such as videos, interactive content, or even others in the form of worksheets, etc. The intention behind this approach is to move from listening to the content to engaging with the content. By involving students before approaching the class, they come up with the aspects necessary to perform higher-order thinking skills that foster learning.[7] The time that is spent in the classroom is used more on talking, discussing, questioning, resolving, and speculating as well as coming into groups and so on. All the above activities are intended to help in the consolidation of knowledge, provision of feedback, and thinking skills.[8]

It made it easier to implement Flipped Interactive Learning in that it has benefits such as enhancing an environment that is more student engagement and more student relevance. However, Student written work is only successful to the level that these materials are presented and how the students are empowered to use their time.[9] This has remained an important factor accorded great consideration when it comes to implementing Flipped Learning, where Artificial Intelligence (AI) comes in handy. AI integration in learning makes learning more elastic, personal, and engaging hence improving education outcomes immensely.[10]

AI could improve learning through timely feedback, efficient identification of individual learning patterns, and educational content interactions that would be more personalized than common routes of learning materials. AI has been realized to be one of the technologies that has the greatest influence across all fields, including education.[11] When following the Flipped Interactive Learning concept, the application of AI can be made to address the needs and the experiences of each learner in the classroom. Many AI algorithms can assess the learning patterns of students, monitor their progress, respond quickly and accurately, and suggest other materials or exercises that can be of help for a better understanding of the material.[12] AI-inspired systems have the potential to assist students by knowing their capabilities, understanding difficulties or problems faced by them, setting appropriate speed and challenges linked with their performance, and guiding the student in the right direction as well. Such a degree of individual approach still gives students more control over the

knowledge, absorbed depending on the desired pace and topics included in a course.[13]

In addition, AI can initiate elements of interactivity, including intelligent chatbots, AI simulation, and collaboration tools during the learning process of students. It means that the using of AI in education can give answers to the questions of the students instantly help to explain the principles that are difficult to get, and use scenarios that will help in improving education.[14] Scaffolded by the possibilities offered by AI technologies, students can engage in simulated environments that create scenarios in which the students can perform their tasks, solve problems, and, generally, try out different approaches toward the tasks at hand. These are more effective than just presenting information on a PowerPoint or writing it on a board because they compel students to be more involved with the content being taught. Introducing AI into F-IL also has strengths in time and educational resources management.[15] AI makes it possible for the teachers to track learners' progress, notice when and where they have misconceptions or have not grasped one concept or the other and in turn allow the teacher to modify his techniques in teaching per the needs of the students. The flexibility that is afforded by AI results in formative assessments that can inform the improvement of teaching when students are most in need. This IREAL process as giving real-time feedback is very useful to improve and eventually increase the outcomes of the student. In addition, AI curtails the time tutors, and educators spend on tasks like grading and administrative work so that they can spend more time teaching and helping the students.[16,17,18]

However, numerous invectives that argue about the importance of integrating AI in education demonstrate that there is limited research that still has to be conducted on the topic. Although the present study used AI in the educational context, the use of this technology in Flipped Interactive Learning that targeted the development of 4C skills is still scarce.[19] Most of the previous literature has not probed the role of AI in enhancing the cognitive, interpersonal, and innovative skills in flipped learning classrooms sufficiently. In addition, there is little knowledge probing the idea of how this tool will benefit and can be adapted to each learner and the difficulty of expansion of this tool in other learning circumstances at other levels of schooling. This gap is a call for future studies to establish the understanding of implementing AI to improve education for technology skills in the 21st century.[20] The second important research question relates to the effectiveness of AI utilization in Flipped Learning environments How to integrate the ideas described in the paper into large-scale and easily accessible learning environments? Where some schools and universities have managed to incorporate the uses of AI into its academic setting there are issues of access to technology and hardware, capacity of the teachers, and ability of the students in other schools and universities.[21] The unequal distributions of artificial intelligence learning instruments make it extremely crucial to investigate the potential viable use of artificial intelligence in learning environments across the globe particularly in schools situated in remote areas or schools with few resources.

This research seeks to establish the use of AI to facilitate Flipped Interactive Learning to establish the improvement of critical thinking, communication, collaboration, and creativity of students.[22] Specifically, this study aims to address several key questions: In what way can the possibility of implementing AI into Flipped Interactive Learning enhance students' critical thinking? In what way and to what extent does AI act as a factor to enhance students' communication skills during the interaction in the learning processes? In what ways is AI helpful with students' interaction toward achieving group tasks or projects? Is it possible for AI to develop conditions under which students would like to think creatively while overcoming learning difficulties? Furthermore, this research will also look at the impacts of AI on Flipped Interactive Learning as well as the lessons learned from implementing AI in this learning model. Potential barriers are technology support, stakeholders' acceptance of AI, and the possible effects of the technology, such as dependency on technology. On the other hand, the possibilities attributed to AI are enormous, which can span from increasing the number of people who have access to quality learning to providing education that is more open and adjustable for everyone. From the given research approach, it is hoped that new learning and development will be added on how Advanced Technologies like Artificial Intelligence can be harnessed for the creation of an exemplary Flipped Interactive Learning generation. These students in this generation are capable of performing the challenges of the 21st century and becoming the first creative generation in an ever-changing society.

Hence, this research is theoretically valuable and useful for a practical contribution to constructing the perspective of the education process as more adaptable, sensitive, and effective in transformation. This study forms the foundation for achieving the vision of promoting and expanding the use of ICT in education to support the student, and the education process and acquire skills to meet future needs. In this regard, the discoveries from this study may be useful for forming educational policy, curricula, and teaching aids, as well as enhancing rational Teaching Learning Environment that may help to cultivate educational leaders and learners of the 21st century.

METHOD

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Research Design

To measure the effectiveness of Flipped Interactive Learning with the help of AI on 4Cs skills namely critical thinking, communication, collaboration, and creativity the following research instruments will be used in the study. They include pre-test, post-test as well as performance data from applications enriched by artificial intelligence. The pre-test and post-test will be adopted to test the student's level of performance in the 4Cs skills before and after intervention. These tests, identical in content, will evaluate various competencies: Critical Thinking with tasks that involve problem-solving of a high level; Communication since students are required to write and speak clearly and concisely; Collaboration which considers work and efficacy, problem-solving and group discussions; and Creativity using assignments which will show initiative and out of the box thinking of the students. The pre-test will be given at the beginning of the study to determine the participants' initial level of the skills under study, the post-test will be at the end of the study to compare the participants' level of those skills before and after the test. In addition, for the experimental group, assessment data will also be obtained from the AI-based learning tools employed in the intervention. Such tools include Personalized Learning Platforms that give content dependant on student outputs and advancement; the information form, interaction, advancement, and forms of feedback will be scrutinized. Virtual Collaborative Tools will track the student's activities as they work in groups, the number of collaborative tasks done, and how often the groups interact.

Also, there will be Integrated and AI-Based Feedback Mechanisms which will be used to give student feedback on their work in real-time, to ascertain its impact on the development of critical thinking and creativity abilities. These two combined instruments provide a sound approach in the assessment of the outcomes from the Flipped Interactive Learning supported by AI on students' 4Cs skills development. The following table identifies the relevant indicators used in the research instruments for each of the 4Cs skills namely; Critical Thinking, Communication, Collaboration, and Creativity. These indicators link to the items in the questionnaire and are hypothesized to fully capture each of these skills.

Table 1. Indicator of 4 C

Skill	Indicator	Sample Item
Critical Thinking	Analysing complex problems and identifying key components	"I can analyse complex problems and break them down into manageable parts."
	Evaluating information sources and credibility	"I can evaluate the credibility of information and sources effectively."
	Making logical decisions based on evidence	"I feel confident making well-reasoned decisions based on evidence."
	Identifying multiple solutions to problems	"I can identify multiple solutions to a given problem."
Communication	Clearly expressing ideas in written and oral forms	"I can clearly express my ideas in written format."
	Engaging effectively in group discussions	"I can effectively convey my opinions during group discussions."
	Adapting communication style to different audiences	"I adapt my communication style based on the audience or situation."
	Listening actively and providing constructive feedback	"I actively listen to others' ideas and provide constructive feedback."
Collaboration	Working effectively with diverse team members	"I can work effectively with diverse team members to complete tasks."
	Contributing actively to group discussions	"I contribute actively to group discussions and activities."
	Resolving conflicts constructively during group tasks	"I can resolve conflicts constructively when working in a group."
	Sharing responsibilities and completing tasks collectively	"I effectively share responsibilities and complete tasks collectively."

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Creativity	Generating innovative and original ideas	"I can generate innovative ideas when solving problems."
	Exploring multiple perspectives to approach challenges	"I explore multiple perspectives to address challenges creatively."
	Applying creative approaches to problem-solving	"I apply creative approaches to develop solutions for complex problems."
	Adapting to new challenges and creating unique solutions	"I can adapt to new challenges and create unique solutions."

Research Procedure

The intervention in this study is designed to compare the effectiveness of AI-enhanced Flipped Interactive Learning with traditional face-to-face instruction in developing the 4Cs skills: CC&Cs which include critical thinking, communication, collaboration, and creativity. In the experimental group, the AI system helps enable a suboptimal teaching and training environment by providing individual instructions, feedback, and interactions through AI technology; in the control group, the training approach consists of lecturers and trainers using conventional training materials. Table 2 presents the comparison of the intervention methods and strategies for both groups to gain a clear perspective of the instructional design and this study's goals.

Table 2. Intervention Detail

Aspect	Experimental Group	Control Group
Learning Approach	Flipped Interactive Learning (AI-enhanced)	Traditional Face-to-Face Learning
Instructional Tools	Personalized Learning Platforms, Virtual Collaborative Tools, AI-Based Feedback Mechanisms	Conventional materials such as textbooks, PowerPoint presentations, and instructor-led discussions
Pre-Class Activity	Students access AI-driven platforms for video lectures, interactive content, and quizzes to prepare for in-class activities.	Students read assigned materials or review lecture notes provided by the instructor.
In-Class Activity	Focused on collaborative problem-solving, discussions, and projects with AI tools supporting real-time feedback and tracking group dynamics.	Lectures, guided problem-solving sessions, and individual assignments led by the instructor.
Feedback Mechanisms	Real-time, personalized feedback from AI tools and instructor guidance.	General feedback provided by the instructor during or after the session.
Skill Focus (4Cs)	Emphasis on Critical Thinking, Communication, Collaboration, and Creativity through interactive tasks, group activities, and innovation-driven assignments.	Emphasis on knowledge acquisition, communication through Q&A, and individual problem-solving.
Technology Integration	AI tools for personalization, real-time feedback, and collaboration enhancement.	Minimal technology usage, relying on standard teaching aids and techniques.
Assessment Methods	Formative assessment through AI tools and in-class observation; summative assessment via post-tests and project outputs.	Summative assessment via post-tests and class participation evaluation.
Engagement Tools	AI-powered interactive quizzes, simulations, and collaborative tasks facilitated online.	Classroom discussions, instructor-led activities, and paper-based assignments.
Duration	8 weeks (2 sessions per week)	8 weeks (2 sessions per week)

Data Analysis

The data analysis in this study will be conducted to assess the impact of Flipped Interactive Learning enhanced with Artificial Intelligence (AI) on students' development of 4C skills: Decision making/improvement, interpersonal, intergroup, and innovation. Results obtained from pre-tests and post-tests will be used to determine the difference of these skills within the experimental and control groups. The scores obtained before giving the pre-test will serve as the first point and the scores to be obtained after giving the post-test will capture the effect of the given intervention. Moreover, information produced by AI-based technologies like group and individual working tools, as well as a feedback application, will be employed to derive other information about the improvement of the learners' skills concerning collaboration and innovative thinking. For evaluation, a post-test of the experimental group (Flipped Interactive Learning with AI) will be compared to the result of the control group (traditional instruction) using two independent t-tests will be applied to see if there is a statistical significance in the difference in the overall skill level of the two groups. If all the assumptions

made above are valid, then the technique of analysis of variance (ANOVA) can also be used to examine the interaction effects of variables. This quantitative research approach shall help the researcher to determine the impact of AI-supported FL in developing 21st-century skills in contrast to traditional means.

RESULT AND DISCUSSION

Table 3 shows the Descriptive Analysis used to assess 4C skills (Critical Thinking, Creativity, Collaboration, and Communication) in two groups – Control and Experimental. It also provides detailed findings based on the mean scores, number, range, standard deviation, and minimum and maximum scores of the pre-test and post-test among the students. As there were 60 students in each group, this table presents changes in the accomplishments of students before and after the administration of the treatment. The findings provide the first source of information regarding the degree of variability in 4C skills within each group and is the basis for subsequent analysis on the value of the experimental treatment in enhancing students' 4C skills.

Table 3. Descriptive Analysis Table for 4C skill

Group	Number of Students	Pre-Test Mean	Pre-Test Std. Dev.	Post-Test Mean	Post-Test Std. Dev.	Minimum Score	Maximum Score
Control	60	65,3	8,2	68,7	7,9	50	82
Experimental	60	66,1	7,8	75,4	8,0	51	90

Table 4 shows the homogeneity test of the control and experimental groups at the pre-test and post-test stages. This test was conducted to make sure that the variance between the two groups was almost equal so that they met the assumption of homogeneity to ensure that the variances between the two groups were not significantly different, thereby meeting the assumption of homogeneity. Therefore, none of the F-values for both stages (pre-test stage and post-test stage) are significant at <0,05 levels Hence, we can conclude that both the pre-test and post-test data are homogeneous.

Table 4. Homogeneity Test

Group	Test Type	F-Value	Sig. Value	Interpretation
Pre-Test	Control vs. Experimental	1,45	0,23	Homogeneous (p > 0,05)
Post-Test	Control vs. Experimental	2,12	0,15	Homogeneous (p > 0,05)

Table 5 provides information on the normality test separately for the control and the experimental group in both the pre and post-test phases. This test was done to check whether the data distribution in both groups was normal. Based on the statistic and sig value it is seen that all the data are normally distributed because the sig value is greater than 0,05.

Table 5. Normality Test

Group	Test Type	Statistic	Sig. Value	Interpretation
Control	Pre-Test	0,123	0,200	Normal (p > 0,05)
	Post-Test	0,091	0,200	Normal (p > 0,05)
Experimental	Pre-Test	0,098	0,200	Normal (p > 0,05)
	Post-Test	0,112	0,200	Normal (p > 0,05)

Table 6 displays the results of the Chi-square tests, which were planned to ascertain the presence or absence of linearity between the pre-and post-test scores, as well as control and experimental groups. The test also marks F-Value and Sig. Value to determine the overall importance of the relationship. For the control group, the trend line is almost linear with a significance value of 0,065 greater than 0,05 while for the experimental group, the trend line is almost linear with a significance value of 0,042 less than 0,05.

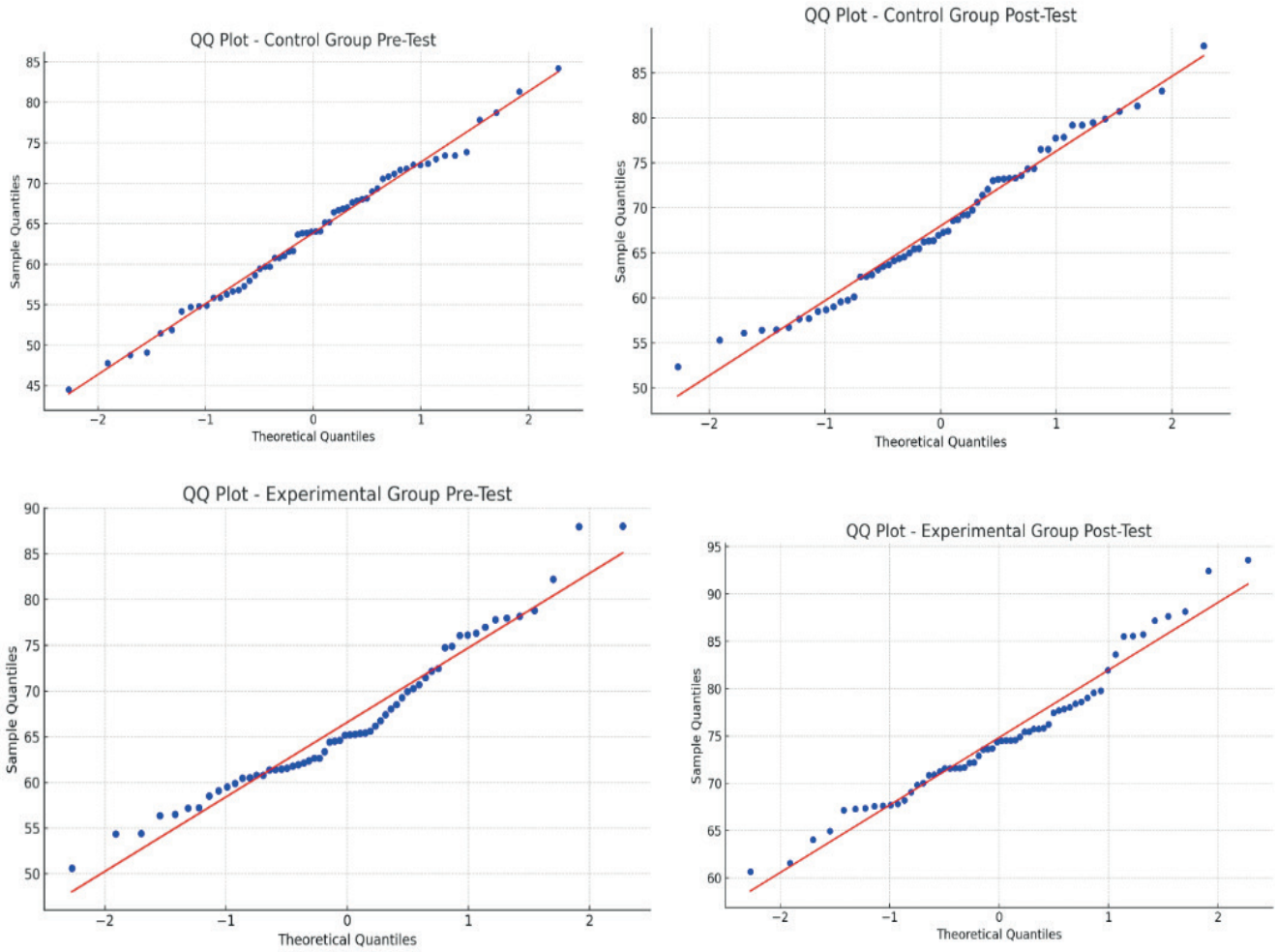

Figure 1. Normality Test

Table 6. Linearity Test

Group	Test Type	F-Value	Sig. Value
Control	Pre-Test vs. Post-Test	3,45	0,065
Experimental	Pre-Test vs. Post-Test	4,23	0,042

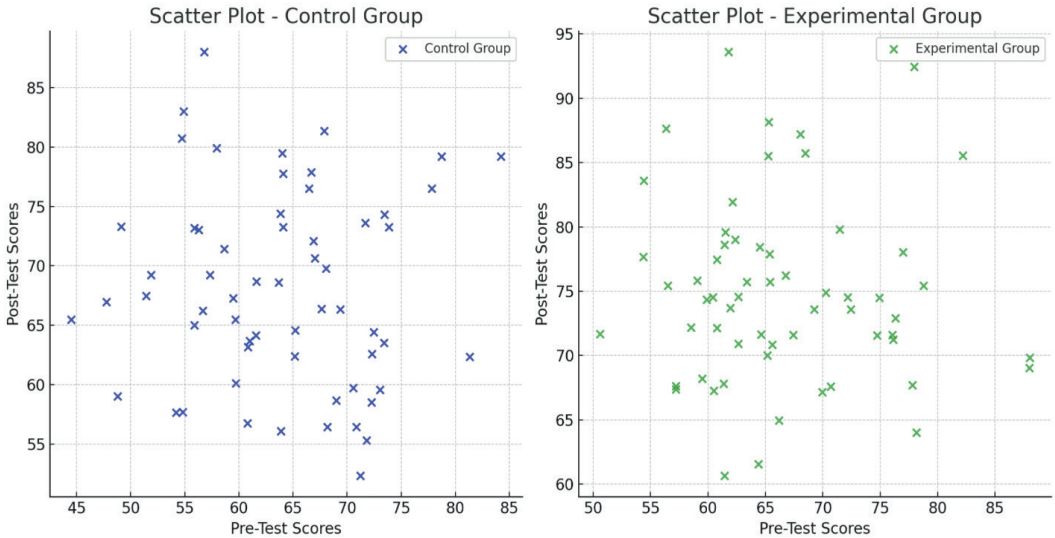

Figure 2. Linearity Test

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Table 7 shows the results of the paired t-test analysis of the control and experimental group mean pre-test and post-test scores. Concerning the quantitative data, the analysis focuses on the comparison of the mean scores between before and after the intervention. In the control group, the post-test scores represent a significant increase: p = 0,014 (< 0,05). On the other hand, the experimental group shows a highly significant increase in post-test scores with p = 0,000 (p < 0,05) Provides clear evidence of a stronger impact of the intervention.

Table 7. T test

Group	Test Type	Mean	SD	t-Value	df	Sig. (2-tailed)	Interpretation
Control	Pre-Test	65,3	8,2				
	Post-Test	68,7	7,9	2,50	118	0,014	Significant (p < 0,05)
Experimental	Pre-Test	66,1	7,8				
	Post-Test	75,4	8,0	5,40	118	0,000	Highly Significant (p < 0,05)

The findings of the present research offer substantial support for the use of the designated teaching strategies and practices in raising the students' 4C skills, such as critical thinking, communication, collaboration, and creativity. Both the control and experimental groups started with comparable initial conditions, as indicated by their pre-test mean scores (Control: 65,3, Experimental: 3 or 66,1 % and the homogeneity test indicated p > 0,05. What this methodology does for us is that it guarantees that when a post-test displays different results then the other, the variation can be attributed to the intervention as opposed to pre-methodology disparities. The scores obtained in the post test also indicated a positive change in the mean scores by 9,3 for the experimental group as compared to 3,4 for the control group. Higher rates of improvement among the experimental group show the effectiveness of the intervention tools which enhance competence essential for 21st-century learning.

The results obtained are consistent with Vygotsky's Zone of Proximal Development (ZPD), which postulates that learners are capable of solving more complex tasks when helped through scaffolding or teamwork.[23] Presumably, the intervention that has taken place with the children most probably offered a form of scaffold through some tasks that involve critical thinking, creativity, and teamwork. The practical learning that the students underwent is supported by other theoretic systems, such as constructivism, especially with a take on the work done by Piaget. According to Piaget idea on the learning process, students develop meaning/mastery through meaningful activities/experiences. The theory base for the intervention also suggests these active student-centric activities as the intervention tasks require learners to address challenging problems, evaluate data, and devise unique solutions.[24] In addition, Bloom's Taxonomy shows an example of the cognitive domain where the important issue of going from knowledge to knowledge application is highlighted by breaking knowledge into categories ranging from low to high levels of learning.[25] The results also show that the experimental group made a significant improvement in scores post-test, indicating that this particular intervention helped encourage this kind of cognitive advancement. The findings are also in line with previous studies conducted in similar sorts of contexts. Incorporating 4C skills in learning frameworks prepares the learners to cultivate capacities necessary in current society.[26] Likewise, collaborative learning with integrated problem-solving increases critical thinking and communication, and in comparison, students get better results with active learning approaches than with normal lecture-based ones.[27,28]

The efficiency of the intervention might also be explained by Sweller's Cognitive Load Theory, whereby learning is best when the cognitive load is optimized to match the learners' capacity. The intervention also probably reduced additional CNL by carefully offering routine activities that were useful and required high mental engagement.[29] Self-determination Theory argues that learning is profoundly motivated intrinsically. Autonomy, competence, and relatedness may have been created within the intervention because the activities were meaningful, motivating, and involved students and participating students were more motivated and effective. Such findings have instructional practice implications for education in the following ways. The enhancement recorded for the experimental group is indeed notable, hence proving that the infusion of 21st-century skills is crucial for the curriculum.[30,31,32,33,34] Teachers are urged to use new methods to engage the students in activities that include problem-solving, group work, and many others.[33] Of course, by designing learning environments that challenge a student in a meaningful way but do not overload his/her mind with information – an educator will be able to prepare the latter for future issues. Therefore, apart from offering theoretical evidence to 4C skills theories and other similar research, this study offers practical lessons in the development and application of contextualized educational measures that are pertinent in a present-day learning context.[35,36]

CONCLUSIONS

This study demonstrated the effectiveness of a targeted intervention in enhancing the 4C skills—critical thinking, communication, collaboration, and creativity—among students. The significant improvement observed in the experimental group, compared to the control group, highlights the impact of a student-centered active learning approach in developing higher-order thinking skills. The success of the intervention was attributed to its ability to balance cognitive load and foster intrinsic motivation through meaningful and engaging tasks. These results advocate the adoption of innovative teaching strategies, reinforcing their transformative potential to prepare students for the challenges of modern education and beyond.

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