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Impacts of active learning strategies on science classes at Colegio San Mateo

Impactos de las estrategias de aprendizaje activo en las clases de ciencias del Colegio San Mateo

Impactos das estratégias de aprendizagem ativa em salas de aula de ciências em Colegio San Mateo

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Abstract

This study, conducted at Colegio San Mateo in Bogotá, investigates the impact of active learning strategies on the motivation and scientific competencies of elementary and high school students. Using an action research approach and a mixed methodological design, 146 students in grades 5, 9 and 10 were evaluated through four interventions (Jigsaw, Hands-on, Interactive Multimedia Resources and Think-Pair-Share). The results showed a significant increase in motivation, participation and acquisition of scientific knowledge, evidencing the effectiveness of these methodologies. The research highlights that active learning transforms education and promotes the comprehensive development of scientific competencies, although its implementation requires rigorous planning and teacher support. In conclusion, active learning strategies optimize academic performance and have a positive impact on the learning experience, fostering scientific skills.

Keywords: Active learning, Science skills, Motivation, Participation, Science education, Pedagogical innovation.

Resumen

Este estudio, realizado en el Colegio San Mateo de Bogotá, investiga el impacto de las estrategias de aprendizaje activo en la motivación y competencias científicas de estudiantes de primaria y secundaria. Utilizando un enfoque de investigación-

acción y un diseño metodológico mixto, se evaluó a 146 alumnos de los grados 5, 9 y 10 mediante cuatro intervenciones (Jigsaw, Hands-on, Recursos Multimedia Interactivos y Think-Pair-Share). Los resultados mostraron un aumento significativo en la motivación, participación y adquisición de conocimientos científicos, evidenciando la efectividad de estas metodologías. La investigación destaca que el aprendizaje activo transforma la educación y promueve el desarrollo integral de competencias científicas, aunque su implementación requiere planificación rigurosa y apoyo docente. En conclusión, las estrategias de aprendizaje activo optimizan el rendimiento académico e inciden positivamente en la experiencia de aprendizaje, fomentando habilidades científicas.

Palabras clave: Aprendizaje activo, Habilidades científicas, Motivación, Participación, Enseñanza de ciencias, Innovación pedagógica.

Resumo

Este estudo, realizado no Colegio San Mateo, em Bogotá, investiga o impacto das estratégias de aprendizagem ativa sobre a motivação e as competências científicas de alunos do ensino fundamental e médio. Usando uma abordagem de pesquisa-ação e um projeto metodológico misto, 146 alunos das 5ª, 9ª e 10ª séries foram avaliados por meio de quatro intervenções (Jigsaw, Hands-on, Recursos Multimídia Interativos e Think-Pair-Share). Os resultados mostraram um aumento significativo na motivação, participação e aquisição de conhecimento científico, demonstrando a eficácia dessas metodologias. A pesquisa destaca que a aprendizagem ativa transforma a educação e promove o desenvolvimento abrangente de competências científicas, embora sua implementação exija planejamento rigoroso e apoio do professor. Em conclusão, as estratégias de aprendizagem ativa otimizam o desempenho acadêmico e têm um impacto positivo na experiência de aprendizagem, promovendo as habilidades científicas.

Palavras-chave: Aprendizagem ativa, competências científicas, motivação, participação, educação científica, inovação pedagógica.

Introduction

This research is framed within the Bilingual Pedagogical Practice of the bachelor's degree in Natural Sciences Teaching at the Universidad de La Sabana, Colombia. Based on a reflection on the predominant challenges in the teaching of natural sciences, the predominant use of passive learning strategies in the classroom was identified, which has a negative impact on students' motivation and learning. Passive learning is characterized by the passive reception of information, where neither feedback nor the active construction of knowledge by students is encouraged, thus limiting the development of scientific skills and the achievement of expected learning (Paul, 2017).

Faced with this problem, the research aims to explore the impact of active learning strategies on the acquisition of scientific knowledge, motivation and student participation. The objectives include designing active learning experiences, evaluating their impact on learning, and creating a bank of online activities with implemented strategies. The study is carried out at Saint Matthew's School in Bogota, a private international educational institution that follows the Cambridge curriculum, serving students from primary to advanced levels.

The research hypothesizes that the implementation of active learning strategies increases the levels of scientific skills development, such as conceptual understanding, and student motivation in natural science classes. The null hypothesis suggests that these strategies do not enhance these levels, while the alternative hypothesis proposes that the implementation of active learning does not generate significant impacts on the development of scientific skills and student motivation in natural science classes.

Background

Theoretical framework

This work assumes the position of active learning, as adopted by Cambridge International Assessment Education (n.d.), which states that this approach promotes the active participation of students in their learning process, based on meaningful experiences that allow the progressive development of knowledge and skills. This

approach is based on various pedagogical theories related to learning processes. Among them, Jean Piaget's constructivist theory stands out, which postulates that students construct their knowledge from experiences that enrich their cognitive structure (Efgivia et al., 2021). In addition, it is based on Lev Vygotsky's social constructivism, which holds that knowledge is socially constructed in a cooperative manner, mediated by culture and language (Saleem, Kausar and Deeba, 2021). It also takes up Vygotsky's Zone of Proximal Development (ZPD) concept and the scaffolding proposed by Bruner and Sherwood, which emphasizes teaching interventions to facilitate the acquisition of knowledge and skills (Gonulal and Loewen, 2018).

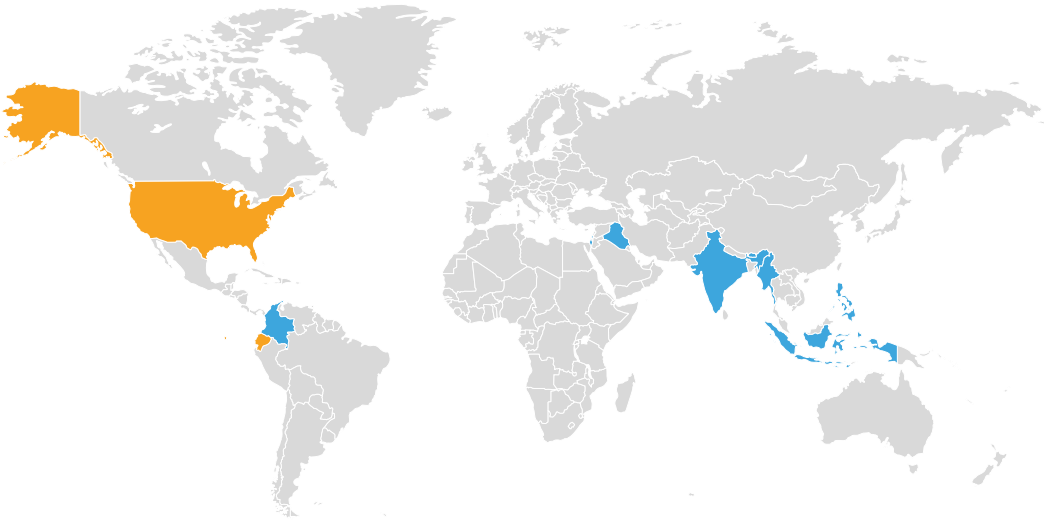
This approach, which incorporates Bloom's Taxonomy (Parakash and Litoriya, 2022), promotes the active participation of students, involving not only actions, but also reflection on these (Dahlaki and Tamimi, 2019; Brame, 2016). Yannier et al. (2021) describe this learning as enriching, meaningful and fun. Finally, studies such as Freeman et al. (2014) and Bonwell and Eison (1991) highlight the positive impact of active learning on academic performance, knowledge retention and critical thinking, as well as its ability to engage students and enhance the educational experience.

State of art

The state of the art was built from the search for research related to the effectiveness of Active Learning strategies carried out only in school contexts (excluding university levels). For this purpose, search equations such as *"Active Learning" AND "Science Classroom" AND "School" and "Effectiveness" and "Active learning" and "School" and "Science"* were used. The search was performed in databases such as Google Scholar and Scopus.

As a result of this search, 12 articles related to the present research's objective were identified, which were published in the last 5 years (2018-2024). Three articles were published in Spanish and the remaining 9 in English. On the other hand, in terms of the countries of publication, despite not finding a clear trend in the data, the United States and Ecuador reported the most related research; the detail of this analysis is set out in Figure 1.

Figure 1. Map and characterization of articles published by country related to the evaluation of the effectiveness of Active Learning strategies.



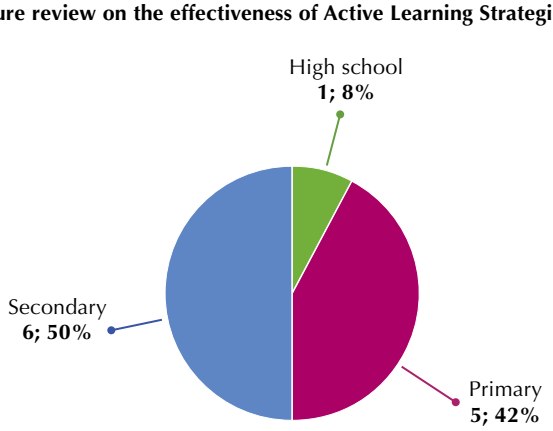
Country	Number of articles
Bhutan	1
Colombia	1
Ecuador	2
India	1
Indonesia	1

Country	Number of articles
Irak	1
Israel	1
Myamar	1
Philippines	1
United States	2

Source: Own elaboration.

On the other hand, the collection of articles was analyzed in terms of the educational levels at which the research was carried out. According to Figure 2, it was identified that 50% of the studies were conducted with secondary school students, 42% in elementary school and the remaining 8% at the high school level.

Figure 2. Distribution of articles by educational level at which they were developed.



Source: Own elaboration.

The review of the state of the art on the effectiveness of active learning strategies in school contexts reveals a notable paucity of research in Latin America, particularly in Colombia. Of the 12 studies identified between 2018 and 2024, 50% focused on high school students. In contrast, research in countries such as the United States and Ecuador has documented significant improvements in academic performance and motivation. This disparity underscores the need to investigate and apply active learning strategies in Colombia, where evidence is limited, offering a crucial opportunity to enrich educational development and student engagement in science.

Active Learning in Primary School

Several studies have explored the efficacy of active learning methodologies in primary education. Dema and Tshering (2020) investigated the impact of active learning on fifth-grade science achievement in Bhutan, reporting significant improvements in student performance and positive attitudes towards the approach. Martella, Klahr, and Li, W. (2020) compared various active learning methods for teaching experimental design, finding more direct forms to be superior in enhancing student learning. Nurmalia, Susilahati, Rosmi, and Sania (2023) demonstrated the positive influence of active learning media on fifth-grade science

and technology outcomes. Mendes Gudalupe (2023) highlighted the importance of active learning resources while emphasizing the challenges teachers face in their implementation due to factors such as lack of training, time constraints, and class size.

Active Learning in Secondary School

Research in secondary education has also focused on the effectiveness of active learning strategies. Hugerat, Kortam, Kassom, Algamal, and Asli (2021) compared problem-based learning with group discussion to traditional methods, finding significant improvements in motivation and classroom climate for the experimental group. Lokhande (2023) and Kyaw & Khaing (2018) both reported superior academic performance and positive student attitudes towards active learning compared to traditional teaching methods in science. Nikko (2022) examined active learning in an online physics course, finding positive student attitudes and potential for improved learning experiences. Hussein & Mohammed (2020) linked active learning to enhanced motivation and performance in chemistry. Torres & Sánchez (2019) emphasized the importance of implementing diverse active learning strategies to foster meaningful learning in science.

Active Learning in High School

Additional studies have delved into the experiences and outcomes of active learning in high school. Barrows (2019) explored student preferences for active and passive learning, highlighting the importance of varied approaches to cater to diverse student needs. Martínez-Velásquez and Riveros-Míguez (2019) successfully implemented an active learning unit on physics, leading to improved student understanding and interest in the subject.

Overall, the presented research consistently supports the efficacy of active learning strategies in enhancing student achievement, motivation, and engagement across different age groups and subject areas. However, challenges related to teacher training, resource availability, and time constraints are identified as potential barriers to widespread implementation.

Methodology

The theory underlying active learning strategies, which emphasizes active student participation and the development of competencies such as critical thinking and collaboration,

should be reflected in the methodological design. In this sense, the present research employs the framework proposed by action research that allows for a continuous and adaptive evaluation of the interventions. This implies the implementation of validated measurement instruments that capture not only academic outcomes, but also motivational and participatory dimensions.

This research investigates the effectiveness of four active learning strategies on motivation, participation, and knowledge acquisition in a population of 146 students from grades 5, 9, and 10. The study employed a mixed research design, in which quantitative data was collected through surveys and pre-tests/post-tests, and qualitative data was gathered through interviews. The selection of the four active learning strategies was made through a process of exploration and initial search, in which it was identified that they promote a dynamic and active learning environment in the science classroom, according to experiences developed in other scenarios.

Selection of participants: 146 students from Colegio San Mateo (grades 5, 9, and 10) were non-randomly selected based on their existing class schedules, according to table 1.

Table 1. Population of students participating in the research.

Cambridge Level	Ages	Grade	Number of students
Primary	5-11 years	5A	25
		5B	22
Lower Secondary	12-15 years	9C	26
Upper Secondary	15-17 years	10A	25
		10B	24
		10C	24

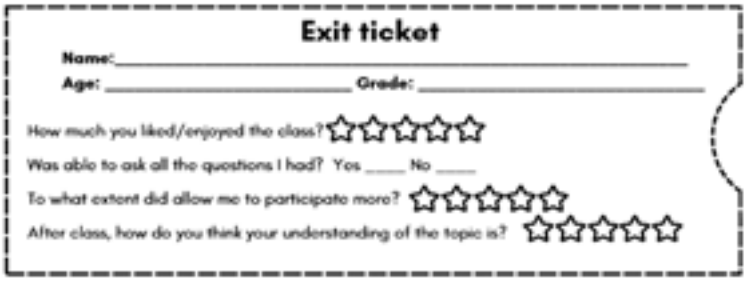
Source: Own elaboration.

Data collection methods

- **Surveys:** Measured motivation and participation before and after the intervention.
- **Pre-tests and post-tests:** Assessed scientific knowledge acquisition.
- **Interviews:** Explored students' perceptions of the implemented active learning strategies.

At the beginning, a pretest was applied with all the courses, with the purpose of inquiring about the current levels of motivation and participation in the natural science classes, through a Likert-type scale (Likert, 1932). Then, the data collection process was carried out in each session. At the beginning of the class, an entry ticket was developed with scientific questions about the topic addressed in the class. In a second moment, the implementation of the active learning strategy (hands-on, Interactive Media Resources, Think - Pair - Share and Jigsaw) was carried out. At the end of the session, the exit ticket was made with the same questions as the entrance ticket, but in addition the students evaluated the Likert-type session considering their motivation, participation and understanding of the class. See Annex X (the attached annex of tickets).

Figure 3. Exit ticket develop in whole classes at the end.



Source: Own elaboration.

Finally, the initial instrument was applied again to determine the impact of the research on students' motivation, participation and knowledge in science classes. Descriptive statistics and statistical analysis were used for data analysis, as described below:

Data analysis methods:

- **Univariate analysis:** Examined the effects of each strategy on motivation, participation, and knowledge acquisition across different grade levels.
- **Pre-post analysis:** Compared students' motivation, participation, and knowledge acquisition at the beginning and end of the research.
- **Qualitative analysis:** Analyzed interview data to identify emerging themes.

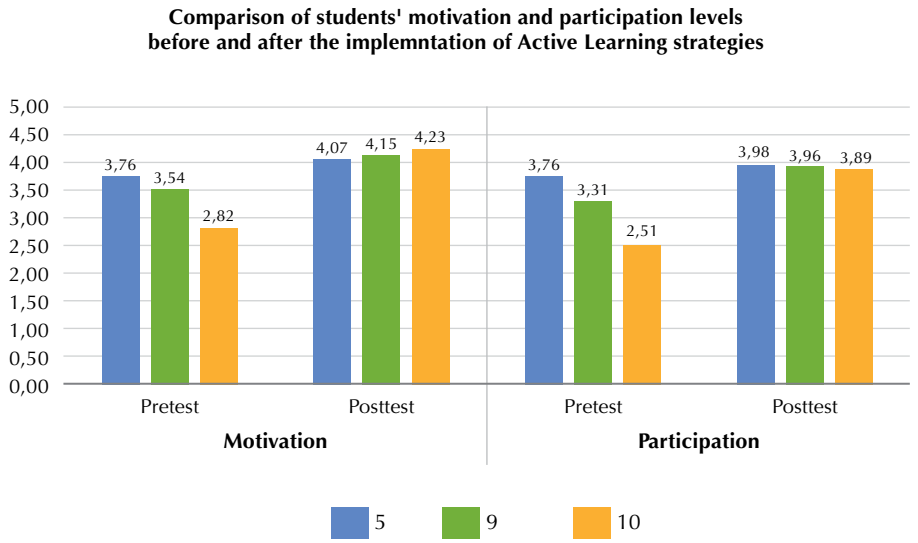
The researchers aimed to demonstrate the impact of active learning strategies on students' motivation, participation, and knowledge acquisition in science classes at different educational level.

Results

The results of the variables under study (motivation, participation and knowledge acquisition), the average values of the students' self-perception at the end of each of the sessions where the four Active Learning strategies were implemented are presented. The values for each variable were established on a scale of 0 to 5.

First, from the results reported in Figure 4, it is possible to identify that all groups experienced an increase in their motivation and participation levels when implementing the four Active Learning strategies.

Figure 4. Significant increase in motivation and participation after implementation of the 4 active learning strategies.



Source: Own elaboration.

Results univariate

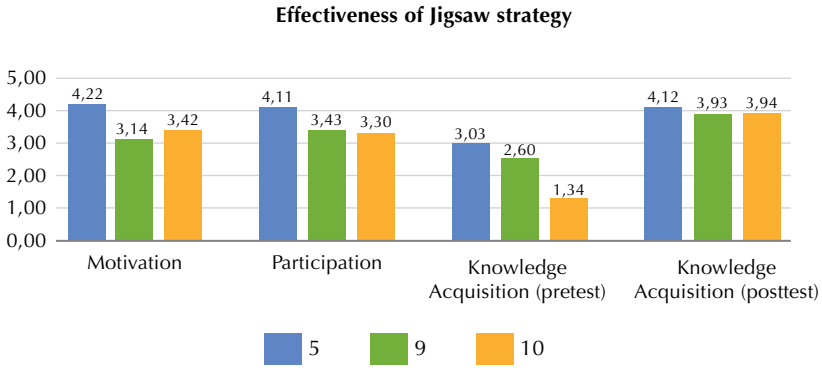
In this case, quantitative data were collected to determine the effectiveness of each Active Learning strategy for the variables of motivation, participation and knowledge acquisition for each grade (fifth, ninth, and tenth).

Effectiveness of the Jigsaw strategy

The results of the Jigsaw strategy's effectiveness in the three grades (fifth, ninth and tenth) are reported in Figure 5

Based on the results, it was identified that the Jigsaw strategy was more effective with fifth grade students in all three variables (motivation, participation and knowledge acquisition).

Figure 5. Effectiveness of the Jigsaw strategy in terms of motivation, participation and knowledge acquisition.



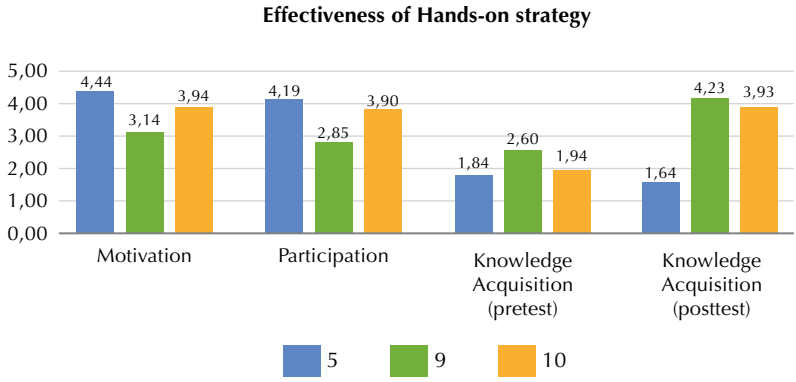
Source: Own elaboration.

Effectiveness of the Hands-on strategy

The results of the Hands-on strategy's effectiveness in the three grades (fifth, ninth and tenth) are reported in Figure 6.

Based on the results, it was identified that the Hands-on strategy, which refers to experimental activities that allow students to interact directly with scientific materials and concepts, had a higher degree of effectiveness with fifth grade students in terms of motivation and participation, however, in relation to knowledge acquisition it was more effective with ninth grade students.

Figure 6. Effectiveness of the Hands-on strategy in terms of motivation, participation and knowledge acquisition.



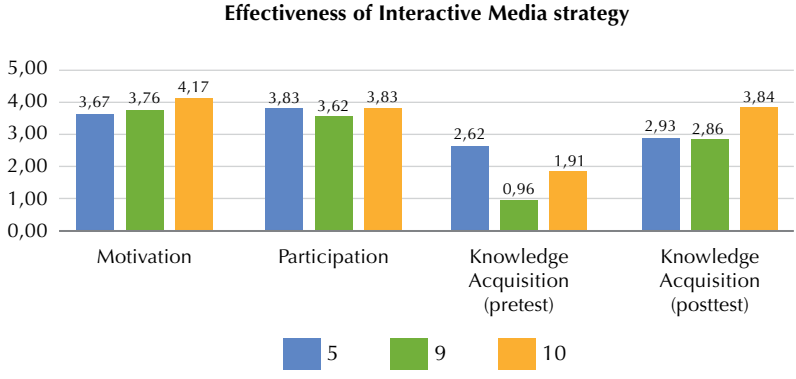
Source: Own elaboration.

Effectiveness of Interactive Media Resources strategy

The results of Interactive Media Resources strategy's effectiveness in the three grades (fifth, ninth and tenth) are reported in Figure 7.

Based on the results, it was identified that the Interactive Media Resources strategy had a higher degree of effectiveness with tenth grade students in the three variables analyzed (motivation, participation and knowledge acquisition).

Figure 7. Effectiveness of Interactive Media Resources strategy in terms of motivation, participation and knowledge acquisition.



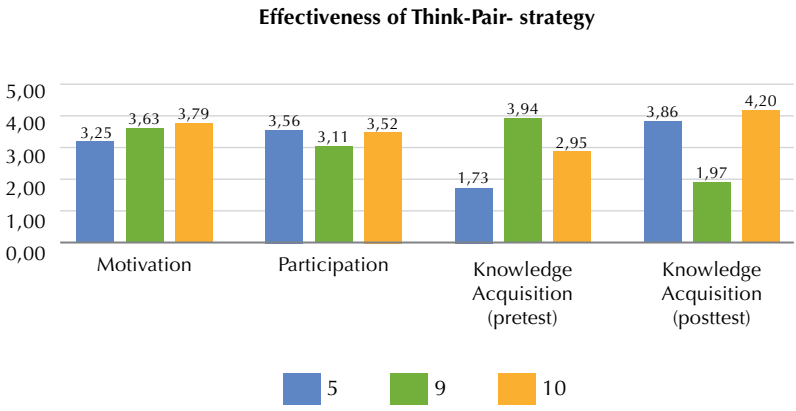
Source: Own elaboration.

Effectiveness of Think – Pair - Share strategy

The results of Think – Pair - Share strategy's effectiveness in the three grades (fifth, ninth and tenth) are reported in Figure 8.

Based on the results, it was identified that the Think-Pair-Share strategy was most effective with tenth grade in terms of motivation and knowledge acquisition, while it favored participation to a greater extent in fifth grade.

Figure 8. Effectiveness of Think-Pair-Share strategy in terms of motivation, participation and knowledge acquisition.



Source: Own elaboration.

Qualitative results

On the other hand, in terms of the qualitative results of the research, derived from interviews with the students of the three levels (fifth, ninth, and tenth), their testimonies were analyzed through word clouds that allowed identifying the words that had a higher frequency, thus allowing the identification of emerging categories for the analysis process. The clouds for each word are shown below.

Table 2. Questions asked students about their experience with active learning strategies.

Question	Fifth grade	Ninth grade	Tenth grade
Do you feel that you are more engaged to learn science by the new teaching strategies developed? Why?			
Do you think the strategies used in the science class make it easier for everyone to actively participate? How?			
Do you think you understood the science class topics better with my strategies? What makes you say that?			

Source: Own elaboration.

Data analysis

The present research that implemented four Active Learning (AL) strategies in fifth, ninth and tenth grade students showed positive results in motivation, participation and knowledge acquisition (Smith & Ragan, 2005; Prince, 2004), evidencing a significant increase in student interest due to the greater sense of control and autonomy provided by AL (Mathias, 2014; Johnson & Johnson, 1989). AA facilitated the connection of the content with students' experiences and interests, increasing the relevance of learning, and an increase in interaction and engagement with the material was observed, improving communication and collaboration skills. Assessments showed better grades in students who participated in AA, associated with deeper understanding and the ability to apply the material

in new situations, developing critical thinking and problem-solving skills (Freeman et al., 2014; Pascarella & Terenzini, 2005). In line with other studies (Cohen, 1994), it is concluded that OA is an effective tool to improve learning, recommending its implementation in classrooms.

The Jigsaw strategy, characterized by the formation of heterogeneous groups and individual responsibility for learning a subtopic to share with the group (Aronson, 1978), proved to be more effective in terms of motivation, participation and knowledge acquisition in fifth grade students. This could be due to the stage of cognitive development of children at this level, where social interaction and the novelty of the cooperative structure of the Jigsaw favor learning (Slavin, 1988). The Hands-on strategy, focused on hands-on and manipulative activities (Langford, 2006), showed a greater impact on the motivation and participation of fifth grade students, while in the acquisition of knowledge it was more effective with ninth grade students. This suggests that hands-on activities are motivating for younger children, but for knowledge consolidation as they advance through the grades, more depth is required than the Hands-on strategy alone can provide.

On the other hand, the Interactive Multimedia Resources strategy, which uses digital tools to enhance learning (Altuve & Rojas, 2018), had greater effectiveness in tenth grade students in the three variables analyzed. This could be due to the greater familiarity and mastery of technologies by high school students, who can take full advantage of the possibilities for interaction and learning offered by these resources. Finally, the Think-Pair-Share strategy, which combines individual reflection with peer discussion and sharing (Lyons, 2001), showed its greatest effectiveness in terms of motivation and knowledge acquisition in tenth grade students, while it favored participation to a greater extent in fifth grade. This suggests that individual reflection and peer discussion may be more beneficial for the motivation and learning of high school students, who have already developed the critical thinking and communication skills necessary to take advantage of this strategy.

Discussion

The research results indicate that the effectiveness of active learning strategies varies by grade level. In fifth grade, the Jigsaw strategy showed greater effectiveness in motivation, participation,

and knowledge acquisition, agreeing with Tamah (2007), who notes that structured collaboration benefits younger students. Hands-on activities were also effective, supporting Balakrishnan et al. (2019), who highlight their appeal to elementary students.

In ninth grade, hands-on activities excelled in knowledge acquisition, suggesting that students better apply theoretical concepts through practical experiences, aligning with Arnold et al. (2006), who argue that these strategies favor experiential learning. However, they were less effective in motivation and participation than in fifth grade.

For tenth grade, interactive multimedia resources were the most effective on all variables, according to Crişan and Enache (2013), who find that older students benefit from advanced technologies. The Think-Pair-Share strategy also showed effectiveness, especially in fifth grade, indicating its flexibility; Muiawan (2020) argues that it fosters the exchange of ideas and critical thinking.

In summary, the effectiveness of the strategies depends on the grade level and requires adaptation to specific needs. The research presents limitations related to classroom management and class frequency; a positive environment facilitates learning, while a low frequency-only on Wednesdays for 16 weeks-may limit the assimilation of concepts.

Conclusions

Active learning has a significant positive impact on education, as it fosters motivation and improves students' scientific skills. These strategies translate into improved academic performance and increased interest in the subject matter. By using methods like problem-based learning and group discussions, students better understand scientific concepts and learn to apply them more effectively. This approach has proven effective at various educational levels, from elementary to high school, contributing to the formation of more competent and motivated students.

However, the successful implementation of active learning depends largely on the teacher's role. Adequate training and availability of resources are critical for educators to effectively implement these strategies. Despite its benefits, some challenges must be addressed, such as the need for more time and resources for preparation, and ongoing training for teachers. Overcoming

these obstacles with the necessary support and resources is crucial to ensure that active learning can be fully developed in the classroom.

On the other hand, in terms of student testimonials, it is identified that student responses indicate a clear preference for hands-on and participatory activities, with a strong inclination towards those that are interactive and fun. Labs and games stand out as particularly effective strategies. In addition, online activities are also well received, reflecting the integration of technology into learning. In summary, to increase motivation, participation, and acquisition of scientific knowledge, it is crucial to design activities that are dynamic, interactive, and engage students' interest.

Finally, results on active learning indicate that these strategies increase motivation and improve students' scientific skills, with important implications for education in Colombia. The implementation of interactive activities can transform the classroom into a more participatory environment, which is essential in the face of the challenges of educational quality and equity in terms of science learning. To achieve this, it is crucial to train teachers and provide them with the necessary resources, which will make it possible to integrate these methodologies in a sustainable manner and improve the quality of education in the country.

Acknowledgments

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