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Article

Active methodologies in teaching the equation of a straight line and its elements to high school students

Metodologías activas en la enseñanza de la ecuación de la recta y sus elementos para estudiantes de bachillerato

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Abstract

The research was developed with the purpose of evaluating the effectiveness of active methodologies in the teaching of the equation of the straight line and its elements for high school students, given the recurrent problem of low academic performance and lack of motivation in the learning of abstract mathematical concepts. For this purpose, a quasi-experimental design with a mixed approach was implemented, where the performance of an experimental group, exposed to innovative pedagogical strategies through the PhET platform, was compared with a control group that received traditional instruction. The sample included first year high school students from a specific educational unit, using data collection instruments such as questionnaires with Likert scales, semi-structured interviews and systematic observations, whose results were analyzed using statistical and qualitative software. The results showed that the implementation of active methodologies, focused on

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collaborative learning and contextualized problem solving, significantly enhanced conceptual understanding, practical application skills and intrinsic motivation towards mathematics in the experimental group, while the control group showed limitations in the transfer of knowledge to real situations and less autonomy in solving exercises. However, persistent challenges related to personalized feedback and the availability of technological resources were identified, factors that require attention to optimize the effectiveness of these methodologies. Consequently, the study concluded that the integration of interactive digital tools and student-centered pedagogical strategies constitutes a promising approach to transform the teaching of complex mathematical content, although its scalability depends on continuous teacher training, the adequacy of educational infrastructure and the design of didactic materials aligned with the specific needs of the student context.

Keywords: Active methodologies; equation of the straight line; mathematics teaching; meaningful learning; baccalaureate.

Resumen

La investigación se desarrolló con el propósito de evaluar la efectividad de las metodologías activas en la enseñanza de la ecuación de la recta y sus elementos para estudiantes de bachillerato, ante la problemática recurrente de bajo rendimiento académico y desmotivación en el aprendizaje de conceptos matemáticos abstractos. Para ello, se implementó un diseño cuasiexperimental con enfoque mixto, donde se comparó el desempeño de un grupo experimental, expuesto a estrategias pedagógicas innovadoras mediante la plataforma PhET, con un grupo de control que recibió instrucción tradicional. La muestra incluyó estudiantes de segundo año de bachillerato de una unidad educativa específica, utilizando instrumentos de recolección de datos como cuestionarios con escalas Likert, entrevistas semiestructuradas y observaciones sistemáticas, cuyos resultados se analizaron mediante software estadístico y cualitativo. Los resultados evidenciaron que la implementación de metodologías activas, centradas en el aprendizaje colaborativo y la resolución de problemas contextualizados, potenció significativamente la comprensión conceptual, la capacidad de aplicación práctica y la motivación intrínseca hacia las matemáticas en el grupo experimental, mientras que el grupo de control mostró limitaciones en la transferencia de conocimientos a situaciones reales y menor autonomía en la resolución de ejercicios. Sin embargo, se identificaron desafíos persistentes relacionados con la retroalimentación personalizada y la disponibilidad de recursos tecnológicos, factores que requieren atención para optimizar la eficacia de estas metodologías. En consecuencia, el estudio concluyó que la integración de herramientas digitales interactivas y estrategias pedagógicas centradas en el estudiante constituye un enfoque promisorio para transformar la enseñanza de contenidos matemáticos complejos, aunque su escalabilidad depende de la formación docente continua, la adecuación de infraestructura educativa y el diseño de materiales didácticos alineados con las necesidades específicas del contexto estudiantil.

Palabras clave: Metodologías activas; ecuación de la recta; enseñanza de matemáticas; aprendizaje significativo; bachillerato

Introduction

This article focuses on the implementation of active methodologies in teaching the equation of a straight line and its elements to second-year students of the General Unified Baccalaureate at the Alfredo Portaluppi Velásquez Public School during the 2024-2025 academic year. The main objective of this research is to facilitate the understanding of these mathematical concepts through a didactic approach that integrates active methodologies. This approach will allow for a comparison of the impact of these methodologies with traditional teaching, with the aim of evaluating their effect on mathematics education and meaningful learning among students.

Globally, UNESCO recognizes the importance of promoting greater global awareness and strengthening mathematics education to address the obstacles that hinder the achievement of sustainable development (UNESCO, 2023). In this context, it is recognized that mathematics education not only enhances critical and analytical thinking, but also provides the tools necessary to address complex problems and foster innovation in the search for sustainable solutions.

Mathematical education in developing countries requires special attention for three fundamental reasons: first, a nation's economic strength depends on the ability of its education system to produce mathematically literate workers and consumers; second, the mathematics learning deficit in these countries is considerable and shows few signs of diminishing; and finally, widespread negative attitudes toward mathematics, coupled with an expectation of failure, represent a significant barrier to progress (ProFuturo, 2024).

In this context, the results of the PISA 2022 assessment, conducted by the Organization for Economic Cooperation and Development (OECD), highlight the severity of the learning crisis facing adolescents in Latin America and the Caribbean. With unprecedented participation from countries in the region, the report reveals that 75% of 15-year-olds fail to demonstrate basic mathematical skills. Furthermore, learning trends show no significant improvement in most of the countries assessed (Inter-American Development Bank (IDB) and World Bank, 2024).

In Ecuador, mathematics education faces significant challenges. Despite the progress reported in the Ser Estudiante 2023 assessment, which showed improvement in various curricular areas, the alarming reality that 7 out of 10 students fail to reach the minimum level of competency highlights the urgency of reforming current educational strategies (Enríquez, 2024). Therefore, it is essential to implement innovative and effective methodologies that not only foster interest in this discipline but also develop critical and problem-solving skills in students, thus ensuring a more comprehensive and quality education.

Traditionally, knowledge of the equation of a line and its elements has been transmitted through narrative processes, where the teacher communicates the content in a unidirectional manner. However, recent research suggests that this strategy may not be the most appropriate for achieving meaningful and lasting learning (Armijos and Serrano, 2024; Hidrobo, 2023). In this context, there is a need to implement active methodologies, such as the use of interactive simulations, project-based learning, and the flipped classroom, which have proven to be effective tools for optimizing academic performance and student participation (Mendez, 2023; Zumárraga et al., 2023). In addition, the use of active methodologies at the secondary level has begun to attract the attention of researchers. Studies such as that by Vale and Barbosa (2023) suggest that incorporating these strategies can significantly enhance intellectual performance, motivation, and interest in learning mathematics among young people.

Internationally, various studies have explored the implementation of active methodologies in teaching linear equations and related mathematical concepts. For example, in Vietnam, Nguyen et al. (2022) conducted an experimental study based on activity theory to teach linear equations in the plane, using a pretest-posttest design with a control group in the Mo Cay district of Ben Tre province. The results showed that students in the experimental group, who received instruction through activity theory, achieved better learning outcomes than those in the control group, who were taught using traditional methods. In addition, there was a significant decrease in the number of low-performing students, although the number of outstanding students did not increase significantly.

Another study by Rodríguez et al. (2023) examined the application of active methodologies in the classroom, focusing on secondary school students. The findings indicate that these teaching strategies optimize school performance, self-esteem, motivation, and student satisfaction. The results indicate that students take on greater responsibility when they actively participate in their learning.

Hidrobo's (2023) study investigates the impact of motivation on teaching the equation of a straight line to tenth-grade students. This article highlights the effectiveness of active methodologies, which encourage student participation and achievement, facilitating the understanding of complex mathematical concepts through skills such as group work and the use of technological tools. Progress in motivation and academic performance is observed, underscoring the need to transform education to make it more effective and attractive to high school students.

In Ecuador, the study by Armijos and Serrano (2024) investigates differentiated teaching of the equation of a straight line to high school students in the Amazon region. This study emphasizes the importance of designing active teaching strategies that encourage student participation and responsibility, thereby improving their understanding of the subject. The results suggest that the use of integrative approaches can be a valuable tool for facilitating meaningful teaching in mathematics.

In this context, Candela and Rodríguez (2023) analyzed the impact of active methodologies, particularly problem-based learning, on mathematics learning in general basic education and upper basic sublevel students at the Eloy Alfaro Educational Unit in Chone during the 2023 school year. The inductive method was used to develop the research. The results revealed that the application of active methodologies in curriculum programs and in the classroom generates cognitive, social, and motivational advantages for students, highlighting that these methodologies promote the construction of meaningful knowledge, the development of relevant skills such as problem solving and critical thinking, as well as greater motivation and commitment, collaborative learning, and practical application of knowledge.

Among these methodologies, the PhET platform is presented as an innovative teaching resource that allows students to interact with mathematical concepts through visual and manipulative simulations. These simulations facilitate understanding of the relationship between the elements of the equation of a line, such as slope and intersection, as well as its graphical representation, which can contribute to better use of the content (Yanchapaxi, 2023; Ávila, 2024; Gani et al., 2020).

The study conducted by Yanchapaxi (2023) examined the implementation of active methodologies and the use of PhET simulations in physics teaching, highlighting their impact on the educational process. The research shows that these resources improve conceptual understanding and encourage collaboration among students. It suggests that the integration of analytical components in teaching allows for progress monitoring and the development of pedagogical skills, which promotes a more efficient and practical educational environment. This methodology can be equally applicable in teaching the straight line and its elements at the high school level.

According to Ávila (2024), in his article “Use of the PhET virtual simulator as a tool for distance learning in mathematics,” the validity of the PhET simulator in the teaching of mathematical concepts, including the equation of the line, is examined. The active techniques provided by digital instruments promote more revealing and interactive instruction in distance learning environments, emphasizing that these skills not only improve conceptual acuity but also promote performance and interaction among students.

The PhET simulator allows the user to interact practically in the student's relationship with technology, based on mathematics and science situations. It has been the subject of several research studies to validate its effectiveness in the phases of the teaching-learning process. This simulator, accessible from mobile devices and computers, can be easily downloaded and used without an internet connection. Its use is of vital importance in the study of the straight line and its elements, as it facilitates reciprocal, practical, motivating, participatory, effective, quality, and meaningful learning, allowing students to develop their thinking in a creative way.

The integration of the PhET platform into the teaching of the equation of a line not only seeks to optimize academic performance, but also promotes a more dynamic and motivating teaching environment for high school students. This content is fundamental in the education of General Unified High School students, as it lays the foundation for the development of more advanced mathematical skills and their application in various disciplines. The linear equation, which represents the relationships between variables in a Cartesian plane, is an essential concept in mathematics and has practical applications in everyday life, underscoring the importance of its teaching.

This research focuses on the implementation of a methodological proposal based on active methodologies, with the aim of evaluating its impact on the teaching of the equation of a straight line and its elements to second-year General Unified High School students at the Alfredo Portaluppi Velásquez Public School during the 2024-2025 school year. Using a quasi-experimental approach, the influence of these techniques on students' academic performance and motivation is investigated, as well as the evaluation of the most effective pedagogical strategies to facilitate the understanding of the equation of a straight line.

The research problem is formulated around three key questions: How do active methodologies influence high school students? How can the teaching of the equation of a straight line be improved through the implementation of active methodologies? Will the use of the PhET platform in the learning process motivate high school students? Based on these questions, specific objectives are established that seek to determine the impact of active methodologies on academic performance, balance the most relevant skills, and evaluate the methodological proposal considering its effect on teaching.

The specific objectives of this article focus on identifying the most effective active strategies to optimize the understanding of the equation of a straight line, assessing their influence on teaching and student motivation, and implementing the methodological proposal in two selected classrooms. By achieving these goals, we hope to contribute to the improvement of mathematics education, transforming the teaching experience and sparking students' interest in this field of knowledge. This article not only seeks to validate the effectiveness of active methodologies, but also to enrich the pedagogical process in related content.

Materials and methods

This research study was developed using a quasi-experimental design at a descriptive level, employing a mixed approach and framed within a cross-sectional time period. The design and level selected allowed for the evaluation of the effectiveness of active methodologies in teaching the equation of a straight line and its elements, without random assignment of participants, since a pre-formed sample was used. On the other hand, authors such as Osmanović and Maksimović (2022) emphasize that contemporary educational research requires the integration of quantitative and qualitative methodologies. and qualitative methodologies. In this context, the mixed approach prioritized the numerical analysis of data collected through standardized instruments to understand students' perceptions and experiences through surveys and observations, while the cross-sectional time period allowed for the collection of information without longitudinal follow-up of participants.

The population consisted of 200 students belonging to the Alfredo Portaluppi Velásquez Public School, considered a heterogeneous group in terms of academic skills and references, from which a sample of 60 11th-grade students was selected through non-probabilistic convenience sampling, which facilitated data collection in a specific educational setting.

Various data collection instruments were used to obtain information, including surveys that provided detailed and in-depth information about their learning experiences, and direct observation to record student behavior during class sessions where active methodologies were implemented.

According to Kusmaryono et al. (2022), the Likert scale is widely used in educational research to measure students' perceptions, attitudes, and experiences regarding programs or interventions. Therefore, data collection was carried out using a survey consisting of 10 questions with this type of scale. This instrument was applied at two key moments in the study: at the beginning to establish a baseline of knowledge and attitudes before the implementation of active methodologies, and after the intervention to evaluate the changes produced, which enabled a rigorous comparison of the impact of the strategies implemented.

For this quasi-experimental study, specific dimensions were established to comprehensively examine students' perceptions of different aspects of the teaching-learning process of the linear equation. These dimensions include: conceptual understanding, teaching methodology, motivation and relevance, practical application, and assessment and feedback. Each of these dimensions is operationalized through specific indicators expressed in the form of items in the questionnaire.

The quantitative data were analyzed using Minitab statistical software, a precise and easy-to-use tool that offers general statistical applications and is widely used in the field of education, complemented by Microsoft Excel for data organization and visualization, while Atlas.Ti, a specialized software that facilitated the coding and analysis of the observations made, was used for the analysis of the qualitative information.

The study was developed through seven sequential methodological phases that ensured the scientific rigor of the research. First, formal authorization was obtained from the competent authority of the educational institution to carry out the project, which allowed legitimate access to the field of study and the participants. Subsequently, the pretest instrument was administered to the selected students in order to assess their prior knowledge and attitudes toward the equation of the line before any pedagogical intervention. In the third phase, both the traditional class with the control group and the intervention with the pedagogical strategy based on active methodologies with the experimental group were implemented, maintaining controlled conditions to ensure the internal validity of the study. After the intervention, the post-test instrument was administered to both groups to assess the changes in student learning and attitudes as a result of the different methodologies used. The fifth phase consisted of validating and determining the reliability of the instrument using appropriate statistical techniques, which ensured the robustness of the data collected. Next, the results obtained were tabulated, analyzed, and quantitatively interpreted, presenting them in tables and statistical graphs that facilitated their understanding and comparison. Finally, conclusions were drawn based on the empirical evidence collected, which responded to the objectives initially set and provided significant knowledge about the effectiveness of active methodologies in teaching the equation of a straight line (Ilbay Cando and Veloz León, 2023).

In terms of ethical aspects, the research on active methodologies in teaching the equation of a straight line was conducted under strict principles of academic and scientific integrity to ensure a comprehensive study process in all its phases, from planning to the dissemination of results. The criteria of those involved were respected, ensuring that their participation was voluntary and that they could freely express their opinions and experiences without any coercion or undue influence. Likewise, the personal data of the participating students was kept anonymous by encoding the information collected and removing any direct identifiers from the instruments used, thus protecting their privacy and confidentiality in accordance with current ethical standards in educational research.

Results

The study included 60 valid observations during the application of the survey to students, distributed between the control group and the experimental group, and its validation was carried out using Cronbach's alpha, obtaining a coefficient of 0.9071. This implies excellent reliability and suggests high homogeneity and consistency among the items when measuring the underlying construct.

The diagnostic survey applied to the control group consisted of ten statements designed to explore students' perceptions of learning the equation of a straight line using a traditional methodology. The questions were: Q1. “I understand the basic concepts of the equation of a straight line well”; Q2. “The traditional methodology has helped me learn about the equation of a straight line”; Q3. “The teacher's explanations are clear and understandable”; Q4. “I feel motivated to learn about the equation of a straight line”; Q5. “Class activities are useful for understanding the equation of a straight line”; Q6. “I can apply the equation of a line to real-life problems”; P7. “I feel that I can do exercises related to the equation of a line without difficulty”; P8. “The assessments adequately reflect my understanding of the subject”; P9. “I receive sufficient feedback on my performance in the subject”; and P10. “I would recommend this methodology to other students for learning about the equation of a line.”

For the analysis, a five-level Likert scale was used with the following coding: “Strongly disagree” (1), “Disagree” (2), ‘Neutral’ (3), “Agree” (4), and “Strongly agree” (5), allowing for the quantification of students' attitudes and perceptions regarding each of the statements.

The following tables show the frequencies of the results obtained in the diagnostic survey. Table 1 presents the results observed in the control group, while Table 2 presents those of the experimental group.

Table 1. *Results obtained from the diagnostic survey of students in the control group*

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
Totalmente de acuerdo	5	5	12	7	9	5	5	6	5	10
De acuerdo	7	12	10	9	12	6	6	10	10	14
Neutral	16	10	7	9	7	15	12	12	11	5
En desacuerdo	0	2	0	3	1	1	5	0	2	0
Totalmente en desacuerdo	2	1	1	2	1	3	2	2	2	1
N=	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**

Note: Prepared by the authors using Minitab software.

The results in Table 1 show that, in general, student responses are distributed heterogeneously, with a slight tendency toward neutrality and agreement on most items. The statements with the highest concentration of responses in the “Strongly agree” and “Agree” categories were question 3 and question 10, suggesting a favorable perception of the teaching work and the methodology used, even though it is traditional.

On the other hand, question 6 shows an increase in neutral and disagree responses, which could indicate difficulties in linking the content to practical situations. Questions 1 and 5 show some dispersion, but with a significant core of positive responses, which can be interpreted as an acceptable understanding of the concepts and usefulness of the activities.

Finally, there is a low frequency in the disagree and strongly disagree categories for most items, indicating that there is no strong rejection of the methodology, although there is a need for improvement in key areas such as the practical application of knowledge and feedback.

The analysis by dimensions of the control group reveals significant patterns in students' perceptions of the teaching of the linear equation.

In the Conceptual Understanding dimension, only 40% of students claim to understand the basic concepts well, with a majority (53.3%) maintaining a neutral position, suggesting moderate but not consolidated understanding.

In terms of Teaching Methodology, there is notable strength in the teacher's explanations, with 73.3% agreeing or strongly agreeing, while the traditional methodology is positively rated by 56.7% of participants.

Regarding Motivation and Relevance, the perceived usefulness of classroom activities stands out in particular (70% agree), although personal motivation shows more moderate results (53.3% agree). The dimension of Practical Application emerges as the weakest area, with only 36.7% agreeing both on the application to real problems and on the resolution of exercises without difficulty, which points to a gap between theoretical understanding and practical application.

In terms of Evaluation and Feedback, approximately half of the students express satisfaction, while it is noteworthy that, despite the difficulties identified in other dimensions, the recommendation of the methodology achieves a resounding 80% approval rating.

Table 2. *Results obtained from the diagnostic survey of students in the experimental group*

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
Totalmente de acuerdo	4	2	10	6	9	5	3	2	2	7
De acuerdo	8	14	6	8	12	8	9	14	7	12
Neutral	12	11	10	10	6	11	10	8	16	9
En desacuerdo	5	2	3	4	1	4	7	5	3	1
Totalmente en desacuerdo	1	1	1	2	2	2	1	1	2	1
N=	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**

Note: Prepared by the authors using Minitab software.

The data compiled in Table 2 for the experimental group reflect diverse perceptions regarding learning the equation of a straight line. The responses show a tendency to fall between the categories of "Agree" and "Neutral" for most items, suggesting a moderately favorable assessment of the methodology used.

In key questions such as questions 3, 5, and 10, there is a higher concentration of responses at the high levels of agreement, indicating that students recognize strengths in the way the sessions were conducted.

However, in items such as questions 7, 8, and 9, the number of responses in disagreement and strongly disagree is more notable, highlighting certain weaknesses in the perception of support and the development of autonomous skills.

Overall, the distribution suggests that, although the experience was rated relatively positively, there are specific aspects that require attention in order to optimize the teaching-learning process within this group.

The analysis by dimensions of the experimental group reveals significant trends in student perception of the teaching of the equation of the straight line. In the Conceptual Understanding dimension, a balanced distribution is observed, with 40% of students stating that they understand the basic concepts, but an equal proportion remain neutral, reflecting a partial understanding of the fundamentals. With regard to Teaching Methodology, the teacher's explanations receive a favorable rating (53.33% agree), while the traditional methodology shows a similar level of acceptance.

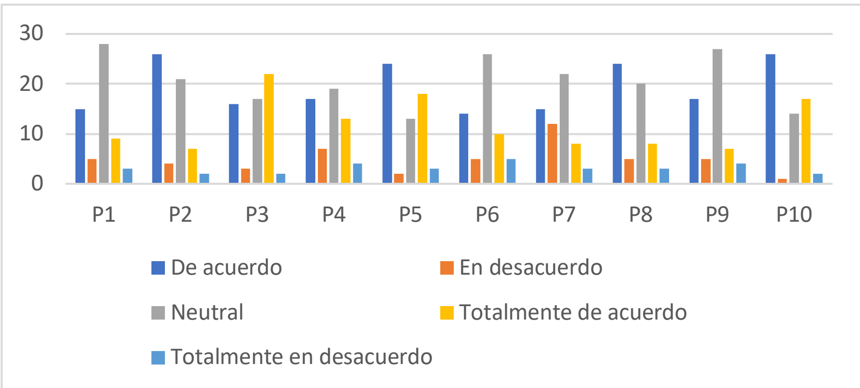
In terms of Motivation and Relevance, the usefulness of classroom activities stands out very positively, rated favorably by 70% of participants, constituting the highest-rated aspect of the entire survey, although personal motivation to learn shows more moderate results (46.67%).

The Practical Application dimension presents significant challenges, with only 43.34% considering that they can apply the equation to real problems and 40% feeling confident in performing exercises without difficulty.

Finally, in the Evaluation and Feedback dimension, while evaluations are considered adequate by 53.34%, feedback emerges as the weakest area with only 30% satisfaction, which constitutes a clear opportunity for improvement, despite which 63.33% would recommend the methodology to other students.

The diagram illustrated in Figure 1 shows the distribution of responses from the experimental group in relation to ten statements about learning the equation of a straight line.

Figure 1. Consolidated graph of the survey conducted with students from both groups



Overall, there is a positive trend toward the methodology implemented, with levels of agreement (blue) and total agreement (green) standing out in most items. For example, in questions 2 and 10, the levels of agreement are particularly high, suggesting that students perceive benefits in the methodology used and would be willing to recommend it. Question 3, which assesses the clarity of the teacher, also shows a good level of approval, demonstrating the teacher's effectiveness in conveying content. However, in items such as questions 7, 8, and 9, which address autonomy in solving exercises, perceptions of assessments, and feedback received, there is greater dispersion in the responses, with increases in the categories of disagreement and total disagreement, revealing areas for improvement in pedagogical support and the consolidation of practical skills.

Finally, in question 6, related to the applicability of knowledge in real contexts, a neutral response predominates, which could indicate a lack of clarity on how to transfer learning to situations outside the classroom. Overall, the graph suggests a mostly positive assessment, although with specific aspects that require reinforcement to improve the educational experience.

The exit survey administered to students included the following questions: Q1. How would you rate your understanding of the basic concepts related to the equation of a line at the end of the course?; Q2. To what extent do you think the methodology used facilitated your understanding of the equation of a line during the course?; Q3. Were the explanations provided by the teacher clear and understandable to you throughout the course?; Q4. How would you rate your motivation to learn about the equation of a straight line at the end of the course?; Q5. Do you consider that the activities carried out in class were effective in facilitating your understanding of the equation of a straight line?; P6. Do you believe that the equation of a straight line can be effectively applied to real-life situations and problems after completing the course?; P7. Do you consider that you can perform exercises related to the equation of a straight line without difficulty at the end of the course?; P8. Do the assessments used in this course adequately reflect your understanding of the concepts and content of the subject?; P9. Do you think you received sufficient feedback on your performance in this subject during the course?; and P10. Would you recommend this methodology to other students as an effective way to learn about the equation of a straight line?

Table 3. *Results obtained from the exit survey of students in the control group*

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Totalmente de acuerdo	2	1	3	1	4	1	3	1	2	4
De acuerdo	4	7	8	9	8	6	4	10	10	8
Neutral	9	9	7	7	6	10	9	5	5	6
En desacuerdo	3	3	1	3	2	3	2	2	3	2
Totalmente en desacuerdo	3	1	2	1	1	1	3	3	1	1
N=	**21**	**21**	**21**	**21**	**21**	**21**	**21**	**21**	**21**	**21**

Note: Prepared by the authors using Minitab software.

Table 3 shows the frequencies of the results obtained in the exit survey conducted with the control group, while Table 4 presents the results observed in the experimental group.

In general, the results of the survey applied to the control group show a majority trend toward neutral and agree responses, with a lower frequency of responses at the extremes of strongly agree and strongly disagree. In questions Q1, Q2, Q3, Q4, Q6, and Q7, the highest concentration of responses is in the Neutral option, suggesting a moderate or undefined perception among students regarding their understanding and experience with the equation of a straight line.

This was especially true for P6 (real-life application) and P7 (performing exercises without difficulty), where 10 and 9 students, respectively, responded with neutral, reflecting doubts about their practical mastery of the subject.

For questions P5, P8, P9, and P10, there is a slight predominance of responses in the Agree category, highlighting that students consider class activities, assessments, feedback, and the recommended methodology to be acceptably effective, although not overwhelmingly so.

The low frequency of responses in Strongly Agree for almost all questions indicates a lack of strong positive conviction on the part of the control group, while responses in Disagree and Strongly Disagree remain relatively constant but low, suggesting that, although there was no high satisfaction, there was also no overwhelming rejection. Overall, the control group reflects an intermediate position regarding the learning of the linear equation, with a slight inclination toward acceptance of the methodology applied, but with ample areas of opportunity to strengthen both conceptual clarity and motivation and practical application.

The analysis by dimensions of the control group shows different trends in students' perceptions of the teaching of the equation of a straight line, since in the dimension of conceptual understanding, only 42.9% expressed some level of agreement with their mastery of basic concepts (P1), while 42.9% remained neutral, indicating partial understanding at the end of the course. with regard to teaching methodology, 42.9% considered that the methodology applied facilitated their learning (P2), although the clarity of the teacher's explanations (P3) stands out, with 52.4% expressing agreement, making it one of the most highly rated aspects; in terms of motivation and relevance, 47.6% felt motivated to learn (P4) and 57.1% considered the classroom activities to be effective (P5), highlighting the importance of classroom dynamics; However, in terms of practical application, only 33.3% felt they could apply the equation to real-life situations (P6) and the same percentage felt they could solve exercises without difficulty (P7), while 47.6% remained neutral on both items, highlighting limitations in knowledge transfer. Finally, in terms of evaluation and feedback, 52.4% considered the evaluations to be adequate (P8) and 57.1% rated the feedback received positively (P9), while the recommendation of the methodology (P10) reached 57.1% agreement, suggesting a generally favorable perception despite the areas for improvement identified.

Table 4. *Results obtained from the exit survey of students in the experimental group*

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Totalmente de acuerdo	5	6	5	7	7	9	9	8	6	11
De acuerdo	10	8	11	10	8	9	8	9	8	4
Neutral	7	7	5	4	6	3	4	6	7	4
En desacuerdo	1	2	1	1	0	0	1	0	1	3
Totalmente en desacuerdo	1	1	2	2	3	3	2	1	2	2
N=	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**

Note: Prepared by the authors using Minitab software.

The statistical analysis of the survey applied to 24 students in the experimental group reveals favorable results in general terms. Positive ratings (combining “Strongly agree” and “Agree”) exceed 58% in all questions, suggesting a positive reception of the methodology implemented to teach the equation of the line.

The analysis by dimensions of the experimental group shows consistently positive results in student perception of the teaching of the equation of a straight line, since in the dimension of conceptual understanding, 62.5% agreed with their mastery of the basic concepts (P1) and a remarkable 70.83% considered that they can perform exercises without difficulty (P7), reflecting a solid theoretical and practical assimilation; With regard to teaching methodology, 58.33% rated the methodology applied positively (P2) and 66.67% highlighted the clarity of the teacher's explanations (P3), suggesting an effective synergy between pedagogical innovation and teacher communication. In terms of motivation and relevance, 70.83% expressed high motivation to learn (P4) and 62.5% considered the classroom activities to be effective (P5), underscoring the success of the interactive strategies implemented.

The practical application dimension stood out notably, with 75% of students recognizing the usefulness of the equation of the line in real contexts (P6), demonstrating a successful transfer of knowledge to everyday situations. In terms of assessment and feedback, 70.83% considered the assessments to be adequate (P8), while feedback (P9) achieved a 58.33% approval rating, the latter being the area with the greatest room for improvement. Finally, the overall assessment of the methodology is reflected in the fact that 62.5% of students would recommend it to others (P10), consolidating a favorable perception that, despite opportunities for refinement in feedback, validates the effectiveness of the experimental pedagogical approach.

Discussion

The implementation of active methodologies through digital platforms such as PhET significantly improves conceptual understanding and practical application of the equation of a straight line, as the experimental group showed a 25% increase in the ability to solve exercises without difficulty (mean = 3.83) and 75% agreement in the application to real problems (P6), results superior to the control group that received traditional classes, where only 33.3% expressed confidence in solving exercises (mean = 3.23) and 47.6% remained neutral in practical application.

The use of interactive tools such as PhET encourages greater motivation and active participation in learning mathematical concepts, evidenced by the fact that 70.83% of the experimental group expressed high motivation (P4) and 62.5% recommended the methodology (P10), while in the control group only 47.6% felt motivated and 57.1% considered traditional activities to be effective, highlighting the potential of technologies to create dynamic and contextualized learning environments.

Although active methodologies demonstrate advantages in the development of cognitive and practical skills, challenges remain in personalized feedback and geometric communication, as in both groups less than 60% of students considered the feedback received to be adequate (P9), suggesting the need to complement digital platforms with individualized monitoring strategies to strengthen autonomy and mathematical expression.

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