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Active learning and knowledge in physics: a reading from classroom work

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Active learning and knowledge in physics: a reading from classroom work

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Abstract. This research article shows the findings of a study that sought to demonstrate the results of a methodological intervention implemented in classes of an eleventh-grade course in the area of Physics, in a public school in the city of San José de Cúcuta, Colombia. The intervention consisted of applying some active learning strategies accompanied by methodological tools such as collaborative work in order to measure the impact of the intervention on the level of disciplinary knowledge of students with a pre-test and post-test. The results show a significant increase with a value of 0.49 at the end of the intervention, which suggests that the subjects participating in the study improved their level of conceptual appropriation in physics after the application of active learning strategies.

1. Introduction

Since the issuance of the [1], Colombia has prioritized the implementation of various pedagogical and methodological strategies to improve the quality of education supported by the different quality references such as curricular guidelines, basic competency standards and basic learning rights for each of the educational areas, within which the strengthening of the teaching profession and institutional improvement have been key [2,3] as well as initial training programs [4,5] and continuous training of teachers where a disarticulation between the pedagogical and disciplinary areas has been established [6,7]. Also, the pedagogical models used in the pedagogical practice of all educational levels are questioned, called transmissionist perspective, where expository type classes are presented, focused on the content [8] and where the role of the teacher is that of possessor of knowledge and that of the students is passive. In the case of Physics teaching, the use of this perspective has implied that students do not conceptualize or develop competencies in the discipline [3].

In addition, teachers must implement in their pedagogical practice criteria to favor a practical understanding of the principles of Physics, as well as its basic learning processes and new teaching methodologies for active learning [9]. However, the former is not always the case, since it has been shown that erroneous models of physics persist, even after receiving university and continuous training, so it is necessary to provide spaces so that disciplinary knowledge can be continuous, applied, questioned and evaluated, since it positively influences their performance as teachers [10].

On the other hand, in recent years, there is evidence of the application of teaching strategies focused on active learning that have improved academic performance and promote meaningful and lasting learning in students by promoting competencies, as opposed to the results obtained with traditional models that hardly achieve this [9,11]. Accordingly, the objective of this study was to determine the impact of a pedagogical intervention supported by active learning strategies on the physics knowledge of middle school students.

Active learning focuses the student at the center of the learning process, promoting collaborative work and knowledge construction by integrating various activities that place students in a performance situation, considering individual tasks, among peers or in teams [10]. Active learning is based on Piaget's constructivist learning theory, which emphasizes the fact that students construct their own knowledge and Vygotsky's social constructivism, where learning takes place through social interaction with teachers and/or peers; complemented by Bruner's with his idea of scaffolding that allows a student to solve a problem, accomplish a task or reach a goal that could go beyond his own effort. Finally, it is based on Bloom's taxonomy, which classifies types of knowledge and cognitive processes used by students to learn [12].

Some active strategies for learning physics can be interactive demonstrative classrooms [13]; inquiry based learning [14-16]; peer instruction [17], context rich problems [18,19], modeling instruction [20], among others.

2. Methodology

The research was conducted under the quantitative paradigm for this purpose a quasi-experimental study was developed with a pretest-posttest design to a single group of students [21], applying the force concept inventory (FCI) [22,23] as a pretest to investigate their initial level of knowledge of the preconceptions of Newtonian physics-mechanics, followed by a methodological intervention supported by active strategies for teaching physics [13-15, 17-20, 24], to end with the application of the FCI as a posttest to recognize the level of knowledge obtained after the intervention and estimate Hake's learning gain [16].

2.1. Population and sample

The population consisted of 83 eleventh grade students in two groups of a public educational institution in the city of San José de Cúcuta, Colombia. The morning group, made up of 43 students, participated as members of the sample. The mean age of the participants was 17.3 years. A 53.5% corresponded to males and 46.5% to females.

Table 1. Distribution by gender.

Options	Frequency	Percentage
Female	20	46.5
Male	23	53.5
Total	43	100.0

2.2. Instrument

FCI is a test designed by [22] and measures the understanding of the basic concepts of Newtonian mechanics, the didactic efficiency of the teaching-learning process of the latter and allows detecting the preconceptions that it has evaluated in this regard [22,23]. The FCI is composed of 30 questions. The advantage of the FCI is that it allows determining the level of knowledge of mechanics, evaluating the didactic efficiency of the teaching-learning process, the degree of understanding, detecting, and classifying the conceptual errors incurred by the students and their preconceptions, and their evolution over time [25,26]. The FCI was used in its Spanish version [18] with questions with 5 answer options, grouped into the following categories [22]: kinematics, Newton's first law (inertia), Newton's second law (force and acceleration), Newton's third law (action and reaction), principle of superposition, types of force; this instrument was used because it measures (in a certain sense) the capacity of Newtonian thinking [27]. A high score on the FCI does not indicate a unified knowledge of the concept of force, however, a low score indicates a lack of knowledge of basic Newtonian concepts.

2.3. Data analysis technique

Hake's factor (g) also called relative conceptual learning gain, indicates the average actual gain of standardized conceptual learning [16]. It is used to determine the level of conceptual learning achievement in the implementation of a didactic strategy, i.e., with the results of an evaluation (pretest and posttest) the impact on the assimilation of the type of conceptual knowledge is determined. In this case, the g factor allows establishing the changes achieved in the different dimensions of the FCI when implementing the didactic strategy with active methodologies, since the low, medium, and high achievement levels in the g factor are related to the level of conceptualization of the FCI. For the calculation of Hake's g-factor, we use Equation (1) [16].

$$g = \frac{\mathrm{FCI_{post}}(\%) - \mathrm{FCI_{pre}}(\%)}{100 - \mathrm{FCI_{pre}}(\%)} \quad (1)$$

This factor can take values between 0 and 1, where 0 represents no learning, while 1 corresponds to the maximum possible learning. Establishing with the relative learning gain it is possible to classify three levels of achievement, these are.

- ⇨ High: $g > 0.7$
- ⇨ Medium: $0.3 < g \leq 0.7$
- ⇨ Lower: $0 \leq g \leq 0.3$

Also, the method of sample comparison for paired samples, student's t-test [28], was applied. Signed authorizations were requested in informed consents designed for the corresponding intervention and data collection, respecting the considerations of ethical standards.

3. Results

The statistical analysis verified the assumptions of the student's t-test for paired samples, which allows comparing the before and after a didactic intervention supported with active strategies [28]. The data suggest that participants increased their level of disciplinary knowledge in physics at the end of the intervention (mean = 85.80; SD = 6.15), compared to that exhibited at the beginning of the intervention (mean = 55.30; SD = 17.75), thus having a statistically significant result ($p < 0.05$; $t = -15.71$; $df = 42$). The effect size found is large ($d = 2.396$) and the power of the test was 99.99%, which exceeds the reference value of 80.0% [29].

An increase of up to 50% is observed in the results, when comparing the performance obtained between the posttest and pretest. Students increased the number of correct answers in all the disciplinary contents addressed by the intervention. This result also suggests the effectiveness of the intervention performed. The discrepant case is not addressed in the present study, given the importance of the overall impact.

Table 2 shows that in the pretest an average performance of 55.27% (SD = 12.67) was obtained and in the posttest the average performance was 85.8% (SD = 7.21). With these data, Hake's gain [16] was calculated, obtaining a value of g = 0.68, which, according to the classification proposed by the same author, corresponds to an average gain, since it is located within the interval greater than or equal to 0.30 and less than 0.70.

Table 2. Paired sample statistics.

	Mean value	N	SD	Average SD
Pre-test	55.274	43	12.6652	1.9314
Post-test	85.807	43	7.2078	1.0992

Table 3 shows, as a complementary analysis, that there are significant differences between the average scores obtained by the students of the group in both tests, with the percentage of the post-test being more favorable.

Table 3. Hypothesis test for paired sample difference.

	Mean	SD	SD average	95% confidence interval of the difference		t	df	Bilateral significance
				Lower	Upper			
Pre-test Post-test	−30.53	12.74	1.94	−34.45	−26.61	−15.71	42	0.000

When analyzing the level of gain per student in the pretest, it was found that 23.3% obtained a gain of less than 0.3, considered low, while 53.3% of the students were at an intermediate gain level, that is, greater than or equal to 0.3 but less than 0.7. Thus, only 23.3% of the participants obtained a level of knowledge considered high.

In comparison, after the intervention with active strategies, the results in the posttest reflect that only 9% of the students were at the low gain level, while the high level increased to 40%. This result shows that the intervention was effective, as it favored a large number of students to move from a low to a higher level of performance, which is evidence of greater conceptual understanding.

Table 4 shows the results of the pretest and posttest from a gender perspective, the results show that women show a greater increase in the average gain compared to men.

Table 4. Average gain earned disaggregated by gender of the student.

Gender	Pre-test	Post-test
Female	55.0%	86.0%
Male	55.5%	85.7%

4. Discussion

The findings suggest that didactic strategies for active learning in the area of physics contribute to improve the level of knowledge, since students obtained greater conceptual understanding at the end of the intervention, achieving conceptual improvement especially in the topic of forces. This result coincides with those obtained in other investigations where active learning methodologies have been used to address disciplinary contents in physics [9].

Active learning strategies reduced gender differences, which shows that the intervention has better results in women than in men. These results are consistent with those obtained by other studies that have suggested that women may benefit more from this type of strategies [30]. The characteristics of these strategies suggest that their use may influence gender differences, given that women tend to express their ideas in participatory activities [31].

However, the results in this regard are not conclusive, as further research is needed to determine which factors of these interactive strategies for teaching physics influence gender differences [32,33].

5. Conclusions

Responding to the research question and by way of conclusion, the evidence suggests that the use of active strategies in the area of physics positively influences the level of knowledge of the students under study, since they manage to learn it and reinforce it while they have the opportunity to reflect with the help of cooperative and collaborative work on how to teach it to their peers. The results indicate that due to the characteristics of these strategies they can influence the reduction of the gender gap, given that women have more opportunities to express their ideas in activities that involve their participation.

Taking into account that the pedagogical practice was always developed with the alternation between cooperative work within small groups of students, as well as with collaborative work through the teacher as a guide of the educational process, it is of interest for a later stage to follow up the teachers in their professional practices. The above suggests incorporating active methodologies from a global vision of the curriculum, since natural sciences expose physics concepts in the course of school life since elementary school.

References

[1] Congreso de la República de Colombia 1994 *Ley 115* (Bogotá: Congreso de la República de Colombia)
[2] Hernández-Suárez C, Avendaño-Castro W R, Rojas-Guevara J U 2021 Planeación curricular y ambiente de aula en ciencias naturales: de las políticas y los lineamientos a la aplicación institucional *Revista de Investigación, Desarrollo e Innovación* **11(2)** 319
[3] Hernández C A, Gamboa A A, Prada R 2021 Desarrollo de competencias en física desde el modelo de aprendizaje invertido *Revista Boletín Redipe* **10(3**) 280
[4] Hernández-Suárez C A, Prada-Núñez R, Gamboa-Suárez A A 2017 Conocimiento y uso del lenguaje matemático en la formación inicial de docentes en matemáticas *Revista de Investigación, Desarrollo e Innovación* **7(2)** 287
[5] Hernández-Suárez C A, Prada-Núñez R, Gamboa-Suárez A A 2020 Formación inicial de maestros: escenarios activos desde una perspectiva del aula invertida *Formación Universitaria* **13(5)** 213
[6] Aguilar-Barreto A, Velandia –Riaño Y R, Aguilar- Barreto C P, Rincón-Álvarez G 2017 Gestión educativa: tendencias de las políticas públicas educativas implementadas en Colombia *Revista Perspectivas* **2(2)** 84
[7] Hernández C A, Núñez P, Rincón G A 2018 Inteligencias múltiples y rendimiento académico del área de matemáticas en estudiantes de educación básica primaria *Infancias Imágenes* **17(2)** 163
[8] Hernández C A 2020 Perspectivas de enseñanza en docentes que integran una red de matemáticas: percepciones sobre la integración de TIC y las formas de enseñar *Revista Virtual Universidad Católica del Norte* **61** 19
[9] Benegas J, Pérez M C, Otero J 2014 *El Aprendizaje Activo de la Física Básica Universitaria* (La Coruña: Andavira)
[10] Hernández-Silva C, López-Fernández L, González-Donoso A, Tecpan-Flores S 2018 Impacto de estrategias de aprendizaje activo sobre el conocimiento disciplinar de futuros profesores de física, en un curso de didáctica Pensamiento Educativo *Revista De Investigación Latinoamericana (PEL)* **55(1)** 1
[11] Rincón-Alvarez G A, Prada-Núñez P, Fernández-Cézar R 2019 ¿Se relacionan las creencias sobre las matemáticas con el rendimiento académico en matemáticas en estudiantes de contexto vulnerables? *Eco Matemático* **10(2)** 6
[12] Krathwohl D R 2002 A revision of Bloom's Taxonomy: an overview *Theory into Practice* **41(4)** 212
[13] Sokoloff D, Thornton R 2004 *Interactive Lecture Demonstrations* (New York: Wiley)
[14] Bybee R 2004 *Scientific Inquiry and Science Teaching* ed Flick L, Lederman N (Dordrecht: Kluwer Academic Publishers)
[15] Schwartz R, Lederma N G, Crawford B A 2004 Developing views of nature of science in an authentic context: an explicit approach to bridging the gap between nature of science and scientific inquiry *Science Education* **88** 610
[16] Hake R 1998 Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses *American Journal of Physics* **66(1)** 64
[17] Mazur E 1997 *Peer Instruction: A User's Manual* (Nueva Jersey: Prentice-Hall)
[18] Heller P, Hollabaugh M 1992 Teaching problem solving through cooperative grouping. Part 2: designing problems and structuring groups *American Journal of Physics* **60(7)** 63
[19] Heller P, Keith R, Anderson S 1992 Teaching problem solving through cooperative grouping. Part 1: group versus individual problem-solving *American Journal of Physics* **60(7)** 627
[20] Hestenes D 1987 Toward a modeling theory of physics instruction *American Journal of Physics* **55(5)** 440
[21] Hernández R, Fernandez C, Baptista M P 2006 *Metodología de la Investigación* (México: Mc Graw Hill)
[22] Hestenes D, Wells M, Swackhamer G 1992 Force concept inventory *The Physics Teacher* **30(3)** 141
[23] Hestenes D, Halloun I 1995 Interpreting the force concept inventory: a response to March 1995 critique by Huffman and Heller *The Physics Teacher* **33(8)** 502
[24] Garritz A 2006 Naturaleza de la ciencia e indagación: cuestiones fundamentales para la educación científica del ciudadano *Revista Iberoamericana de Educación* **42** 127
[25] Huffman D, Heller P 1995 ¿What does the force concept inventory actually measure? *The Physics Teacher* **33(3)** 138
[26] Henderson C 2002 Common concern about the force concept inventory *The Physics Teacher* **40** 542

[27] Morris G, Harshman N, Branum-Martin L, Mazur E, Mzoughi T, Baker S D 2012 An item response curves analysis of the force concept inventory *American Journal of Physics* **80(2)** 825
[28] Sheskin D 2007 *Handbook of Parametric and Nonparametric Statistical Procedures* (New York: Chapman & Hall)
[29] Connolly P 2007 *Quantitative Data Analysis in Education: A Critical Introduction Using SPSS* (New York: Routledge)
[30] Lima P, Rezende F, Ostermann F 2011 Diferenças de gênero nas preferências disciplinares e profissionais de estudantes de nível médio: relações com a educação em ciências *Ensaio Pesquisa em Educação em Ciências* **13(2)** 119
[31] Pollock S J, Finkelstein N D, Kost L E 2007 Reducing the gender gap in the physics classroom: How sufficient is interactive engagement? *Physical Review Physics Education Research* **3(1)** 010107:1
[32] Kohl P B, Kuo V I 2009 Introductory physics gender gaps: Pre-and post-studio transition *American Institute of Physics* **1179(1)** 173
[33] Hernández-Suárez C A, Prada Nuñez R, Gamba Suarez A 2020 Using concept maps to understand mechanical physics concepts in high school students *J. Phys. Conf. Series* **1672(1)** 012019:1