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GUIDED INDAGATION AS A METHODOLOGICAL STRATEGY FOR THE DEVELOPMENT OF SCIENTIFIC COMPETENCES IN MIDDLE EDUCATION STUDENTS

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Abstract. Technological advances require the development of scientific thinking in which students can access and transform their environment. This tends to teach an updated, contextualized and motivating science which awakens interest in students and that emphasizes in the development of scientific competences. Under this premise, the objective of this article is to present the results obtained when implementing a methodological strategy based on a guided inquiry, on the adjustment of physics laboratory practices. The strategy was carried out in three schools of Bogotá (Colombia) in a research consisting of 145 students from secondary education, monitoring the interactions of students employing the follow-up process in the interaction whit laboratory practices model, and analyzing the progress of their performances inherent to the competences suggested in the research. From a mixed methodology, analytical descriptive, were implemented *ad hoc* designed input and output tests, which establish the level of appropriation of competencies, before and after the implementation of the methodological strategy. The results obtained show the effectiveness of the strategy within the educational contexts considered. It is concluded that the strategy presents an innovative and relevant character, since it proposes guiding and didactic elements for the teaching of science, bringing students closer to the new technological and scientific developments of today

Keywords: guided inquiry, methodological strategy, scientific competences, laboratory practices, secondary education.

LA INDAGACIÓN GUIADA COMO ESTRATEGIA METODOLÓGICA PARA EL DESARROLLO DE COMPETENCIAS CIENTÍFICAS EN ESTUDIANTES DE EDUCACIÓN MEDIA

Resumen. Los avances tecnológicos requieren del desarrollo del pensamiento científico con el cual los estudiantes puedan acceder y transformar su entorno. Esto propende por la enseñanza de una ciencia actualizada, contextualizada y motivadora que despierte el interés en los estudiantes y que privilegie el desarrollo de competencias científicas. Bajo esta premisa, el objetivo del presente artículo es presentar los resultados obtenidos al implementar una estrategia metodológica basada en la indagación guiada, en la adecuación de prácticas de laboratorio de física. La estrategia se implementó en tres colegios de Bogotá (Colombia), en una muestra conformada por 145 estudiantes de educación media, efectuando el seguimiento de las interacciones de los estudiantes con el modelo de prácticas de laboratorio propuesto, y analizando los progresos de sus desempeños inherentes a las competencias sugeridas en la investigación. Desde una metodología mixta, de corte descriptivo analítico, se implementaron pruebas de entrada y salida diseñadas *ad hoc*, que establecieron el nivel de apropiación de las competencias, antes y después de la implementación de la estrategia metodológica. Los resultados obtenidos dan cuenta de la efectividad de la estrategia al interior de los contextos educativos considerados. Se concluye que la estrategia presenta un carácter innovador y relevante, al proponer elementos orientadores y didácticos para la enseñanza de las ciencias, acercando a los estudiantes hacia los nuevos desarrollos tecnológicos y científicos actuales.

Palabras clave: indagación guiada, estrategia metodológica, competencias científicas, prácticas de laboratorio, educación media.

Introduction

Worldwide, educational research has established that the number of young people interested in pursuing scientific careers has fallen sharply in recent decades (Pedrinaci, Caamaño, Cañal, & de Pro, 2012). The lower enrollment rates in these careers have led to growing concern (Daza-Caicedo, et al., 2011) due to the impact that science and technology have on the economic and social development of countries.

For this reason, studies have been carried out to identify the factors that directly influence the students' lack of motivation. Among them, the study carried out by Sjøberg and Schereiner (2010) stands out. Its results show that adolescents' low intention to choose a profession related to science, technology, engineering and mathematics is a product of the difficulties involved in learning science and the low incidence of science education in critical thinking.

Rocard, et al. (2008) identified that one of the reasons why young people do not develop an interest in science is the presentation of overloaded and obsolete programs, an abstract approach to knowledge without the support of observation or experimentation, as well as ignoring the direct relationship between current events and their social implications.

For its part, the Organization for Economic Cooperation and Development (OECD) through the Program for International Student Assessment, known as the PISA test, especially in its 2006 test, whose focus was on science, as well as on student performance measurement and knowledge measurement based on the concept of scientific literacy, included questions to investigate students' attitudes towards science and technology from three particular areas: interest in science, support for scientific

research, sense of responsibility over resources and the environment. All this considering that these aspects are related to performance, career choice and lifelong learning for the OECD (OCDE, 2006). In this study it was observed that, although young people highly value the contributions made by science, which contribute significantly to the knowledge of the world, only 21% think that they would pursue a scientific career (Gutiérrez, 2008). In the 2015 test, the vast majority of students expressed a high interest in scientific subjects and acknowledged their role in the world, but only 25% said they wanted to pursue a career in science. It was also found that time spent learning science and how it is taught are closely related to students' interest in scientific careers. It was also observed that students with better results in this field stated that their science teachers explain or expose scientific ideas more frequently, and adapt their teaching to their needs (OCDE, 2016).

At the national level, Colombia has been conducting several perception surveys on science and technology. Specifically, in 2009, the Colombian Observatory of Science and Technology (OCyT), together with the District Secretary of Education (SED), conducted a study (Daza-Caicedo, et al., 2011) with 6,428 high school students in 28 schools in Bogotá, 13 in the public sector and 15 in the private sector. It describes students' perceptions of the scientific and engineering professions, the career opportunities they offer, the image they have of science and scientists, and the different assessments students make about how science subjects contribute to their lives (Daza-Caicedo, et al., 2011). Concerning the last two points, it should be noted that one of the factors most highly valued is the difficulty and tedium that scientific subjects can bring. Therefore, it is considered decisive in the lack of motivation towards choosing scientific careers.

On the other hand, the lack of an adequate scientific literacy that allows students to pursue scientific careers is evidenced by lower performance in international (PISA) and national assessments (Saber 11). Specifically, PISA tests show that the competences assessed in sciences include cognitive processes of special meaning and relevance for their teaching (Bybee, 2004). In this regard, specifically in 2006, of 57 participating countries, only 38.59% achieved a score above the average established by the OECD (500); Colombia ranked 53rd. In 2015, of 70 countries assessed, only 42.85% scored above the OECD average (493); Colombia ranked 57th (OECD, 2007; OECD, 2016). These percentages indicate that the level of scientific literacy worldwide does not even reach 50% of the participating countries.

At the national level, the Colombian Institute for the Assessment of Education (ICFES) is the body responsible for evaluating, through standardized tests, the education received by Colombians at different educational levels. Specifically, the SABER 11 test evaluates the appropriation of competences in students who have completed secondary education. Thus, four performance levels are established in each one of the areas. Level 4 is the highest, where the student employs concepts, laws or theories in solving problems through procedures, skills, knowledge and the specific language of science. In level 1 performance (the lowest), students barely recognize explicit information and demonstrate the insufficient development of inquiry competence. According to the results obtained in science in the Saber 11 tests, applied in 2015 and 2016, it is observed that the students of calendar A schools obtain results that place them at level 2, while the results of the students of calendar B schools place them on levels 2 and 3 (ICFES, 2017).

In order to strengthen the acquisition of scientific competences, the incorporation of inquiry processes in science teaching promotes the implementation of practices in students, where theoretical knowledge is used along with scientific skills and attitudes; thus promoting the development of this type of competences (Crujeiras and Jiménez, 2015). Thus, "the educational process in sciences by inquiry allows the student to assess scientific curiosity and the capacity for analysis as a learning source, and to use the everyday environment as a close element in science didactics, ideal for fostering significant learning" (Torres, 2010, p. 138). All this, within an ideal scenario such as laboratories (Högström, Ottander, and Benckert, 2010), where the practices developed there lead students to spaces for the development of scientific knowledge (conceptual, procedural and attitudinal) and relating it to culture, technology and society. In this regard, Séré (2003) points out that practical work leads to an epistemological awareness in students, who understand the varied relationships between theory and experience in experimentation. In addition, a greater impact is achieved when the action is interdisciplinary.

Therefore, this study's purpose was oriented towards the implementation of a methodological strategy that not only stimulates a more dynamic interaction of students in science classes, awakens curiosity and generates a true appropriation of scientific knowledge, but also promotes the development of scientific competences specifically with middle school students, adopting for this purpose a research methodology applied to laboratory practices.

Method

Specifically, this study aims to determine to what extent guided inquiry as a methodological strategy promotes the development of competences in secondary school students.

Design

In consistency, participatory action research is applied (Álvarez-Gayou, 2003), hand in hand with the sociocritical paradigm (Arnal, Del Rincón, and Latorre, 1992). The design was conceived from a mixed perspective, adopting a descriptive and interpretative approach, and incorporating triangulation.

Participants

The population is represented by students and middle school teachers from three (3) formal education institutions located in the city of Bogotá: Colegio Hunzá, Colegio San Simón and Colegio Abraham Lincoln. These institutions broadly represent the characteristics of the city's schools, by taking into account aspects involved in the educational context, present in each of the participating institutions. These schools are located in different localities and socioeconomic strata, have different academic calendars, some belong to the public or private sector of education and present different results throughout their participation in SABER 11 tests, as described in Table 1.

Table 1
Institutional characterization of the population under study.

Parameters / School	**Hunzá**	**San Simón**	**Abraham Lincoln**
Type of institution	Public	Private	Private
Academic calendar	A	A	B
Stratification	1-2	3-4	5-6
SABER 11 test category (2016)	B	A+	A+
SABER 11 test place (2016)	764	278	26

The sample (Table 2) is made up of students from one of the tenth and eleventh grade groups of the three educational institutions, according to accessibility and availability criteria for participation in the study.

Table 2
Selected sample

School/ Grades	**Hunzá**		**San Simón**		**Abraham Lincoln**	
	Grade	**No. of students**	**Grade**	**No. of students**	**Grade**	**No. of students**
10th	1001	36	1001	23	10A	16
11th	1101	35	1101	15	11A	20
Total		71		38		36

Instruments:

Different instruments were used to implement the methodological strategy:

1. An *entrance exam* that allowed to investigate the level of appropriation of the scientific competencies that would be strengthened with the implementation of the methodological strategy. The design of this exam was divided into two parts. The first one included questions with only one answer, where the appropriation of three of the competencies proposed in the research was investigated: *use of particular codes of science (CU), procedural and experimental (PE)* and *reflexive and critical thinking of science (RCT)*. For this purpose, a set of 50 questions taken from standardized tests applied at the international level (PISA) and national level (Saber 11) in the last 5 years was formed, which showed a relationship with the proposed competencies and allowed to guide the way they should be elaborated. The items were selected based on the analysis of key material available in web pages[1], provided by entities with relevance in the matter. After a rigorous study, 15 questions were selected and adapted to validate

[1] PISA exam e-mail addresses: http://educalab.es/inee/evaluaciones-internacionales/preguntas-liberadas-pisa-piaac/preguntas-pisa-ciencias/fisica;http://educalab.es/inee/evaluaciones-internacionales/preguntas-liberadas-pisa-piaac/pisa-por-ordenador; http://www.mecd.gob.es/dctm/ievaluacion/internacional/ciencias-en-pisa-para-web.pdf?documentId=0901e72b8072f577; www.oei.es/evaluacioneducativa/tipo.pdf
Direcciones electrónicas pruebas Saber 11: http://Cuadernillo%20de%20 preguntas-Saber%2011-%20Ciencias%20naturales.pdf; http://Guia%20de%20orientacion%20saber%2011-2017-1%20(2).pdf; https://orientacion.universia.net.co/imgs2011/imagenes/cuadernill-2016_11_03_145738.pdf

the level of appropriation of each of the competences proposed in the research (5 for each competence). For the selection and wording of the questions proposed in the test, criteria of relevance, clarity, coherence, complexity, relevance were mainly taken into account.

For the validation of this instrument, a *theoretical validity* was implemented based on the review of the literature presented in the theoretical framework of the research and a *content validity* conducted through the method of individual aggregates, where judges formed by external peers (3) reviewed the questions presented in the exam. *The selected* judges[2] reviewed the proposed exam from a rubric with the categories that were taken into account in the design. In order to complement the validation process of the exam, a pilot group was considered, made up of 10 students from Abraham Lincoln High School (5 10B-students and 5 11-B students) and 10 students from Hunza High School (5 1102-students and 5 1002-students). On the basis of the observations made by the students, the time allotted to the test and the editing of one of the proposed graphs were adjusted.

The second part of the test presented a Likert type questionnaire that investigated the perceptions that students had about group work (fourth proposed competence) assigning to the proposed items scores between 1 and 5, being 1 the lowest score and 5 the highest according to their perceptions. For the reliability of this instrument, an initial questionnaire was applied to the pilot group and after carrying out a refinement process, a Cronbach alpha of .92 was obtained, proposing a total of 5 items for this part of the test.

2. A *laboratory program sheet* was also used, from which the proposed practices in each educational institution were organized, specifying themes, material, types of laboratory to be implemented and the spaces in which each practice would be carried out according to the schedule of the different groups.

3. Likewise, *the progress section of the laboratory practices* was designed to record the progress or difficulties detected in the students when interacting with the proposed methodology. Through this section, assessments were assigned to the performances involved in each competition.

4. Finally, a *leaving test* was used, implemented to establish the impact of the methodological strategy based on the advances in the scientific competencies that were sought to be developed in the research. The procedure adopted for the elaboration and validation of this instrument was the same as that adopted for the entrance test.

Procedure

In the design phase of the implementation, a previous diagnosis was used to establish the appropriation of the approach by competencies in the institutions under study, carried out through interviews with rectors and teachers, the study of institutional documents (Institutional Education Project, IEP (in Spanish, PEI), documents in the area of natural sciences and curricula), and the application of a sociodemographic survey that made it possible to identify socioeconomic aspects, family and students' interest in science.

[2] *Juries: Head teacher at the Research Center and teacher of Knowledge Theory at Abraham Lincoln School; Physics teacher at Abraham Lincoln School; University Teacher and PhD in Education.*

Subsequently, according to the literature review, it was decided to establish the competencies that would be strengthened in the research, each with their respective performances: Use of particular codes of science (CU), Procedural - Experimental (PE), Reflective and Critical Thinking of Science (RCT), and Teamwork (TW) [3].

In this design phase, a model of laboratory practices was proposed under the research methodology (Benarroch, 2015¸ Caamaño, 2012), which considers the implementation of experimental practices through a series of phases: 1) Focusing phase; 2) Exploration phase; 3) Verification and contrast phase; 4) Results socialization phase; and, 5) Application phase. The process includes the exploration of previous ideas on some subjects, the formulation of hypotheses, the approach of procedures, the confrontation of predictions on the obtained results approached in a logical and argumentative way. Subsequently the knowledge is exposed and disseminated in order to be applied in new situations in which it is transferable.

Concretely and to carry out this design, in a *first phase* the entrance test was applied in each one of the groups of the three educational institutions. Once this information was collected, the results were tabulated and coded for analysis.

In a *second phase*, in a meeting with the tenured teachers, the results of the *entrance exam* obtained in each grade were socialized and analyzed. Likewise, the work plan to be carried out in each grade was carried out through the *laboratory program card* instrument, establishing the laboratory practices that were developed in accordance with the study plan of each subject. Finally, meeting sessions were scheduled with the tenured teachers to provide feedback on the process and aspects of the development of the practices.

The *third*[4] *phase* gave way to the realization of laboratory practices under the new methodology. Once each practice was completed, the approaches presented by the students were reviewed using the *practical laboratory progress rubric* instrument, which assigned a specific evaluation to the performances proposed in the different experimental practices for each of the competencies. Once the interaction of the students with the implemented strategy was finished, an analysis was made of the

3 *Use of particular codes of science (CU)* that refers to the socialization of knowledge, the use of particular communication codes through which the construction of semantic structures is proposed so that they can be interpreted by the members of a community; *Procedural - Experimental (PE)* that emphasizes the contrast of the theoretical with reality through experimentation through the implementation of a series of procedures that involve skills related to material manipulation, assemblies elaboration, appropriate use of instruments and data processing, manipulation of computerized tools and technological material and the accomplishment of some activities that imply the follow-up of instructions by the students, among others; *Reflective and Critical Thinking of Science (RCT)*, emphasizes that the solution of problematic situations involves the integration of knowledge in a proactive and creative way, which requires an adequate development of cognitive processes involving basic thought processes allowing students not only analyze and explain scientific phenomena, but build knowledge from them; and *Teamwork (TW)*, develops the ability to interact with others in a group and individual way, awakening a sense of belonging, responsibility and efficiency when making confrontations of ideas, celebrating agreements and tackling tasks together.

4 These practices were developed by one of the female researchers, who was accompanied, during each class session, by the head teacher of the subject. The teacher presented an attitude of interest and enthusiasm, since the way in which the experimental activities were carried out aroused astonishment and interest in knowledge. In the same way, little by little impressions of each session were collected, which were socialized in the scheduled meeting meetings in order to obtain the necessary feedback to nourish aspects of the implementation.

progress achieved in each competence from the evaluations obtained in the proposed performances in each of the experimental practices.

In a *fourth phase*, the application of the *final test* instrument was carried out, with which, in a first part, the level of appropriation of scientific competences reached after the implementation of the methodological strategy was established again. In the second part, the Likert questionnaire used in the entrance test was implemented to identify any change in the students' appreciations about teamwork.

Finally, in a *fifth phase*, the results of both the entry test and the leaving test were analyzed through an analysis of variance that allowed to establish the impact of the proposal.

Results

On the results obtained in the *entrance test*, the average of the answers given was initially obtained from the situations proposed from each competence obtaining a general average (Tables 3 and 4).

Table 3
Achievement of tenth grade students in the competences assessed on the entrance test

School	**Hunzá**		**San Simón**		**Abraham Lincoln**	
Skill	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
UC	36.56%	63.44%	53.92%	46.08%	66.26%	33.74%
PE	33.14%	66.86%	47.84%	52.16%	73.78%	26.22%
PRC	33.14%	66.86%	48.68%	51.32%	76.28%	23.72%
Average	34.28%	65.72%	50.14%	49.85%	72.10%	27.89%

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

Table 4
Achievement of eleventh grade students in the competencies assessed on the entrance test

School	**Hunzá**		**San Simón**		**Abraham Lincoln**	
Competence	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
UC	47.68%	52.32%	55.98%	44.02%	76.00%	24.00%
PE	34.62%	65.38%	51.98%	48.02%	70.00%	30.00%
PRC	36.14%	63.86%	49.63%	50.64%	68.00%	32.00%
Average	39.48%	60.52%	52.53%	47.47%	71.33%	28.66%

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

From the results obtained in the *entrance test* (Table 3), it can be observed that the students of Abraham Lincoln School presented a higher level of appropriation of the competencies to be strengthened in research in both the tenth and eleventh groups. The above can be attributed, to a certain extent, to the type of training offered by this institution, Baccalaureate (IB) where the methodology of investigation is constantly privileged not only within experimental practices, aspect evidenced in the diagnosis at the beginning of the research. In addition, it was also observed that low results obtained

in every competence, both by the tenth and eleventh grade students of the Hunzá School, were similars, as well as the general level valuations. Something similar was presented in the tenth and eleventh grade students of San Simón School. However, the general average of the results in this last institution was more acceptable, without ceasing to show that there is not an adequate appropriation of the competencies proposed for research[5].

With respect to the second part of the test that investigated the students perceptions in relation to group work (*TE* competence), the assessments from 1 to 5 were grouped into: low score (1 to 2), acceptable score (3) and high score (4 to 5) (Table 5).

Table 5
Perception of teamwork (competence TE) entrance test

School	Grade	Tenth			Eleventh		
	Assessment / Item	Low	Acceptable	High	Low	Acceptable	High
Hunzá	1	11.4%	20.0%	68.6%	7.7%	26.9%	65.4%
	2	5.7%	20.0%	74.3%	3.8%	26.9%	69.2%
	3	8.5%	20.0%	71.5%	11.5%	7.7%	80.8%
	4	11.4%	22.9%	65.7%	15.3%	19.2%	65.4%
	5	2.9%	17.1%	80.0%	3.8%	26.9%	69.2%
San Simón	1	8.3%	4.3%	86.9%	6.7%	13.3%	80.0%
	2	8.7%	26.1%	65.2%	13.3%	20.0%	66.7%
	3	26.0%	4.3%	69.5%	6.7%	13.3%	80.0%
	4	17.3%	34.8%	47.8%	0.0%	20.0%	80.0%
	5	8.7%	21.7%	69.6%	6.7%	6.7%	86.6%
Abraham Lincoln	1	0.0%	6.3%	93.8%	15.0%	10.0%	75.0%
	2	0.0%	6.3%	93.8%	5.0%	5.0%	90.0%
	3	6.3%	12.5%	81.3%	25.0%	10.0%	65.0%
	4	6.2%	12.5%	81.3%	10.0%	20.0%	70.0%
	5	0.0%	0.0%	100.0%	10.0%	20.0%	70.0%

From the results obtained, it was observed that in tenth grades of the Hunzá and San Simón Schools, and in the eleventh grades of Hunzá and Abraham Lincoln, a more rigorous work in relation to the group work dynamics must be done. However, although the students percentage who assigned low and acceptable ratings to the items investigated did not exceed 35 %, when implementing the proposal it was sought that this percentage decrease.

With respect to the progress of the students in each competency for the practices analyzed and, according to Figure 1, it was observed that in Hunza school, specifically for grade 1001, although the initial assessments were not the same in each skill greater progress was presented in the *UC* competency. The skill that had less progress was *PRC*, which is consistent with weaknesses observed within the guides. These are related to the approach of predictions, the presentation of arguments that accounted for the

[5]This is in line with the previous diagnosis carried out in these educational institutions, which showed the low incidence of activities tending to develop scientific skills and the absence of appropriation of research methodologies.

validity of the set of data collected, the appropriate drafting of conclusions and the identification of the objective of the practice.

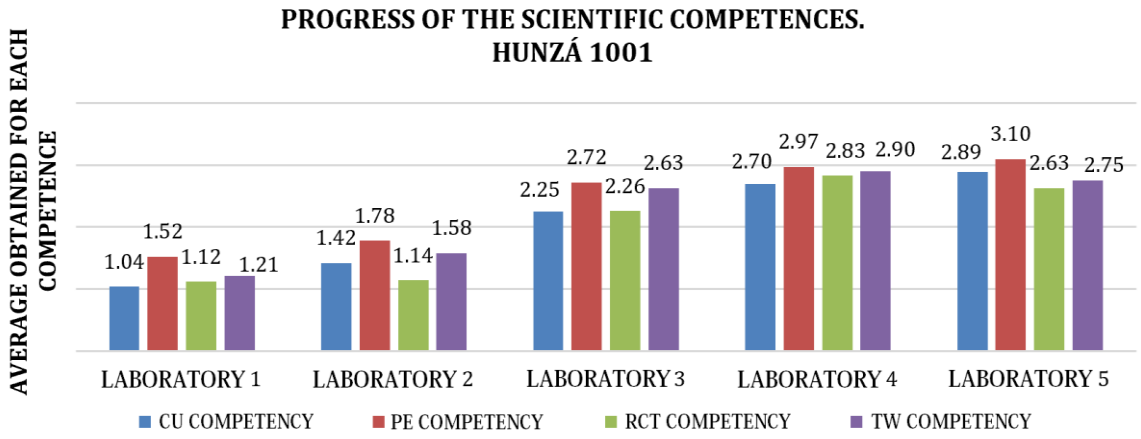

Figure 1. Competences progress in Hunzá School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

In this same institution for grade 1101, according to Figure 2, it was observed that the averages of the competencies were very similar in each laboratory practice. As in grade 1001, there was greater progress in the *UC* competency. The competence that revealed less progress was PE, aspect that was in agreement with weaknesses observed inside the presented guidelines. These are elated to the adequate elaboration of predictions, the proposal of procedures that allow the collection of information to validate a prediction and the adequate organization of information through tables.

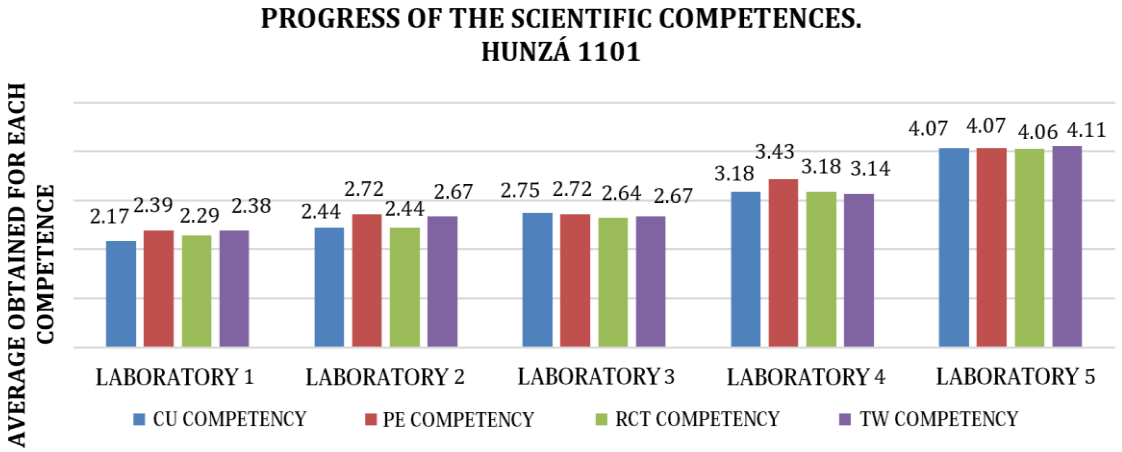

Figure 2. Competences progress in Hunzá School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

In San Simón School, according to the results shown in Figures 3 and 4, it was observed that, although the assessments in each competence were not similar to each other, their progress was greater than that evidenced in each of the Hunzá School grades. Specifically in grade 1001, the proficiency that made the most progress was *PRC*. The competence that showed the least progress was *UC* associated with difficulties specifically related to the use of an adequate scientific language in the explanation of phenomena and the contextualization of practice

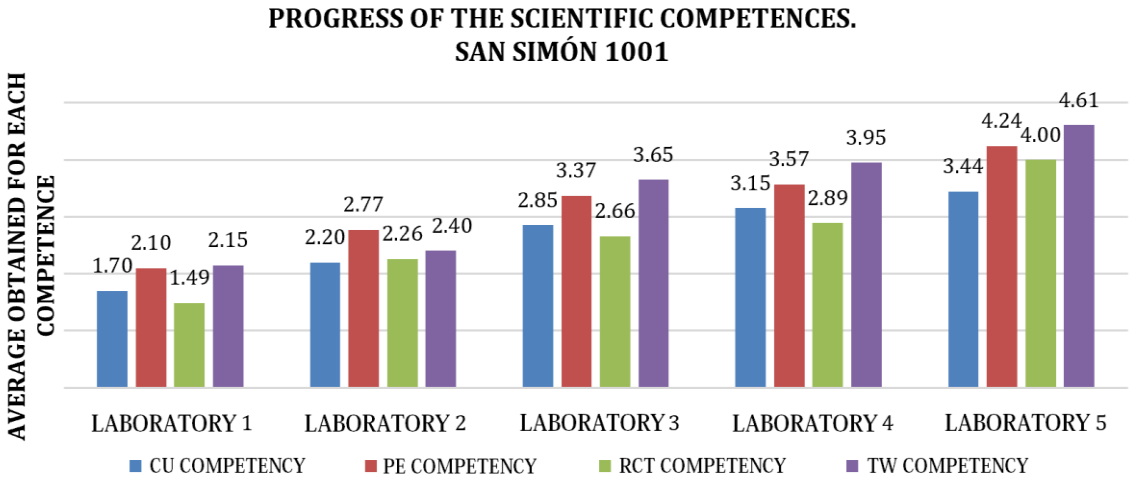

Figure 3. Competences progress in San Simón School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

In grade 1101 of San Simón School, it was seen that as in grade 1001, the competence with the greatest progress was *PRC*. The competence with the least progress was *PE* related to difficulties observed within the guides related to the elaboration of predictions and the proposal of procedures that allow information to be collected to validate a hypothesis.

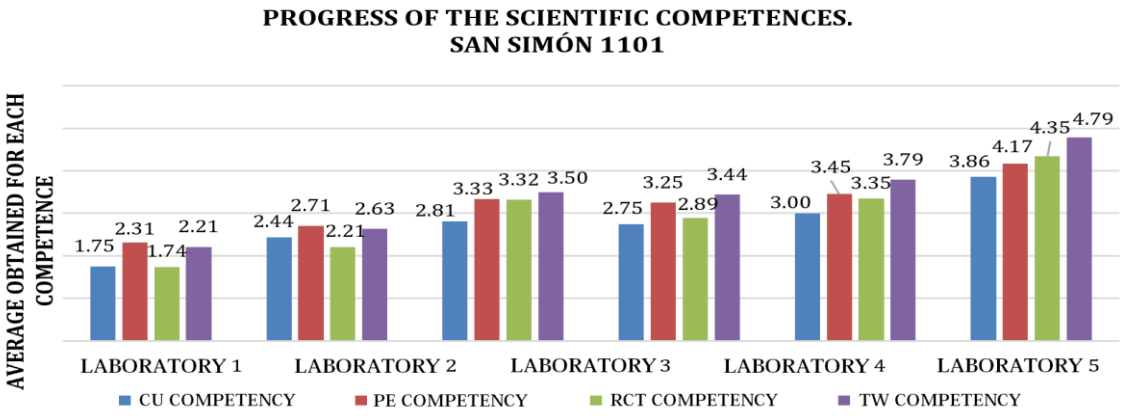

Figure 4. Competences progress in San Simón School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

Besides that, Abraham Lincoln School was the educational institution where there was the least progress in the competences, although it should be noted that the ratings assigned in each of them were the highest.

As the Figure 5 shown, there was a greater progress in the *TE* competence, specially in grade 10A; while the competence with less progress was *UC* related to difficulties observed within the guidelines, specifically with the elaboration of some arguments.

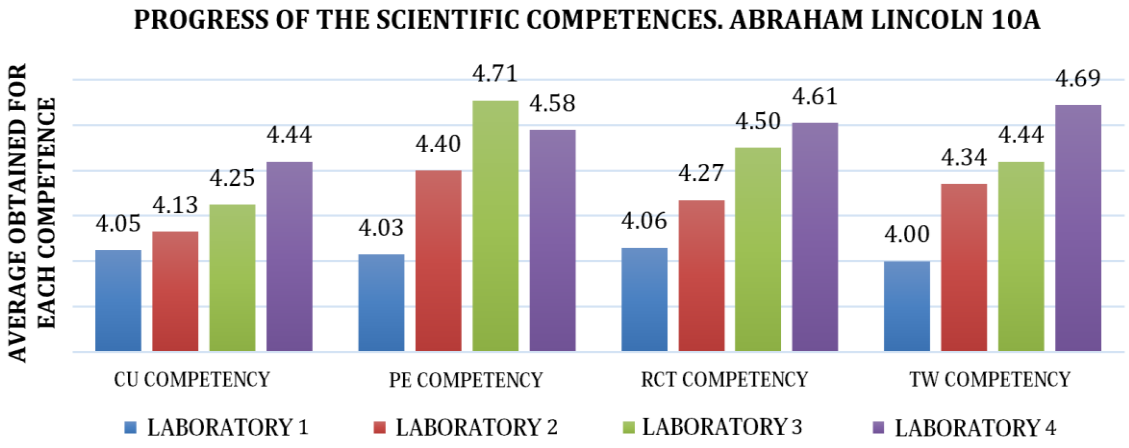

Figure 5. Competences progress in Abraham Lincoln School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

At grade 11A, there is greater progress in PRC competence, and similarly, the one that made the least progress was UC, also associated with difficulties observed inside the guides, in relation to what concerns the arguments elaboration (Figure 6).

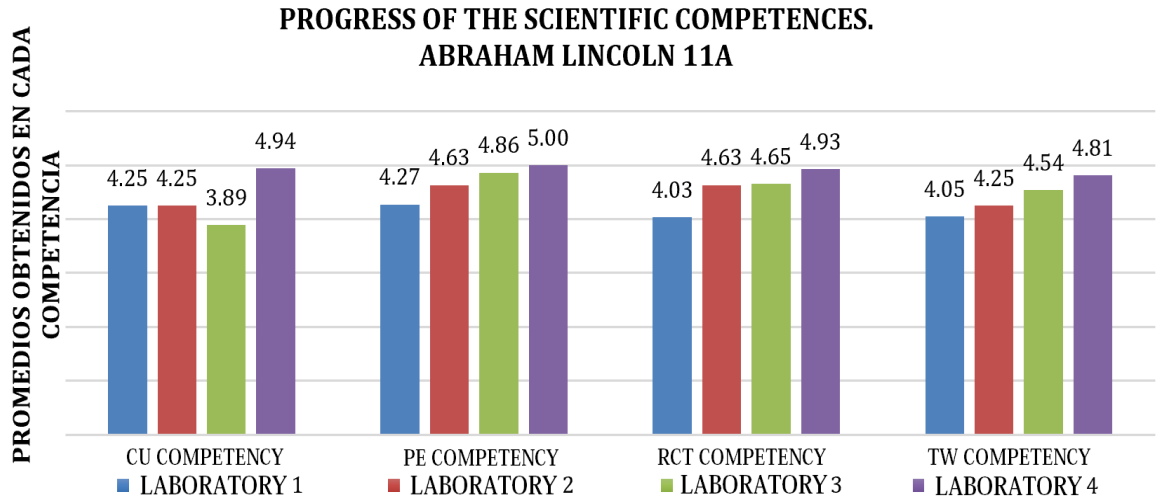

Figure 6. Competences progress in Abraham Lincoln School 1101

Note: UC: Use of Particular Science Codes Competence; PE: Procedural-Experimental Competence; PRC: Reflective and Critical Thinking of Science Competence.

Finally, feedback on the weaknesses and strengths in student productions before initiating a new practice made it possible for more significant advances to be made in the performances within the new practices.

With regard to the tabulation of the results obtained in the *exit test*, similar to the *entrance test*, the average of the answers given from the situations proposed in each competence was obtained (Tables 6 and 7).

Table 6
Assessment of 10th grade students in the competences assessed on the exit test

School	**Hunzá**		**San Simón**		**Abraham Lincoln**	
Competence	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
UC	65.15%	34.85%	69.57%	30.43%	72.5%	27.4%
PE	56.0%	44.0%	59.13%	40.87%	82.5%	17.5%
PRC	37.14%	62.86%	55.65%	44.35%	76.25%	23.75%
Average	52.76%	47.24%	61.45%	38.55%	77.08%	22.92%

Table 7
Assessment of 11th grade students in the competencies assessed in the exit test

School	**Hunzá**		**San Simón**		**Abraham Lincoln**	
Competence	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
UC	71.54%	28.46%	76.0%	24.0%	87.0%	13.0%
PE	53.08%	46.92%	68.0%	32.0%	82.0%	18.0%
PRC	40.0%	60.0%	54.67%	45.33%	73.0%	27.0%
Average	54.87%	45.13%	66.22%	33.78%	80.7%	19.3%

Examining the results obtained in the *exit test*, again Abraham Lincoln students present the highest scores despite the fact that, as mentioned, their progress in the competencies during the interaction with the methodological strategy was not as significant as with the other two schools.

It was also observed that the results obtained by Hunzá students in both grades show a significant increase. The performance in relation to the *UC* competence, whose valuation is higher, stands out, which is in line with the progress evidenced during the interaction with the methodological strategy.

On the other hand, although the students of the San Simón school also showed a significant increase in the results, it should be noted that, in particular, those competencies that showed significant progress during the interaction with the new methodological strategy were those that obtained the lowest results in the exit test, which could be attributed to the high level of complexity of the questions proposed in this competition, since, as can be observed, in all grades of the educational institutions, the PRC competition was where the lowest scores were presented, with the exception of grade 10A of Abraham Lincoln School. This indicates that it is definitely difficult for students to perform advanced mental processes where a higher level of analysis and deduction is required. Finally, it should be noted that the highest rated competence was *UC* in all grades of the three educational institutions.

From the results obtained in the first part of the entrance and *exit* tests, the statistical analysis T Studen[6] was carried out, which allowed a hypothesis test to be carried out and with it to establish the impact of the proposed methodology.

In this way, the hypotheses that were sought to be tested were:

H_o:

- The average of the results obtained in the entrance test is greater than or equal to the average of the results obtained in the exit test.

H_a:

- The average of the results obtained in the *exit* test is higher than the average of the results obtained in the entrance test.

To carry out this statistical analysis, the SPSS computer program was used, with which a normality test was initially performed through the nonparametric Kolmogorov-Smirnov test.

Finally, in order to establish whether the Null Hypothesis (HO) or the Alternate Hypothesis (Ha) was adopted, the respective P-value for each of the degrees was determined with the same SPSS computer program, as described in Table 8. For this purpose, a significance level of 5 %, i.e. $\alpha = .05$, was defined, thus establishing a confidence level of 95 %.

Table 8
Calculation of the P-value

	Tenth	**Eleventh**
	P-value	**P-value**
Hunzá	.0006	.0007
San Simón	.0040	.0080
Abraham Lincoln	.261	.086

Note: For $P < \alpha=0.05$ the null hypothesis is rejected and the alternate hypothesis is accepted.

Thus, it was observed that the P-value achieved for the Hunzá and San Simón school grades indicates that the implementation of the proposed methodology was feasible for the strengthening of scientific competencies. Not so in the Abraham Lincoln High School grades, this could be related to the fact that this group, having a background in inquiry methodologies, did not show a significant change in the final test results.

However, returning to the second part of the *exit test*, which gives an account of the students' appraisals of group work, again applying the questionnaire proposed in the entry test and grouping the appraisals given by the students from 1 to 5 in: low appraisal (1 to 2), acceptable appraisal (3) and high appraisal (4 to 5), the data obtained were recorded in Table 9.

[6] This statistical analysis was used because there were quantitative variables (entry and exit test results) from the same group (in each grade), which were measured before and after.

Table 9
Perception of teamwork (competence TE) output test

School	Degree	Tenth			Eleventh		
	Assessment / Item	Low	Acceptable	High	Low	Acceptable	High
Hunzá	1	0.0%	11.4%	88.6%	0.0%	3.8%	96.1%
	2	2.9%	14.9%	82.9%	0.0%	19.2%	80.7%
	3	5.7%	14.3%	80.0%	0.0%	3.8%	96.1%
	4	5.7%	14.3%	80.0%	0.0%	19.2%	80.7%
	5	5.7%	5.7%	88.6%	0.0%	7.7%	92.3%
San Simón	1	0.0%	8.7%	91.3%	0.0%	13.3%	86.6%
	2	4.3%	17.4%	78.3%	0.0%	0.0%	100.0%
	3	0.0%	13.0%	86.9%	6.7%	0.0%	93.3%
	4	8.7%	21.7%	69.6%	0.0%	26.7%	73.3%
	5	0.0%	21.7%	78.3%	0.0%	0.0%	100.0%
Abraham Lincoln	1	0.0%	6.3%	93.8%	0.0%	15.0%	85.0%
	2	0.0%	0.0%	100.0%	10.0%	5.0%	85.0%
	3	0.0%	12.5%	87.6%	5.0%	15.0%	80.0%
	4	0.0%	6.3%	93.8%	10.0%	15.0%	75.0%
	5	0.0%	6.3%	93.8%	15.0%	0.0%	75.0%

When analyzing the results obtained in the *exit test*, it was found that the percentage of students who assigned low and acceptable scores to each of the items decreased significantly, which evidences a higher score compared to the dynamics given within a group work.

Discussion and conclusions

In relation to the objective proposed in the present study, after having implemented the methodology of guided inquiry in physics laboratory practices, it was evident that there was a significant progress in the appropriation of the scientific competencies proposed within the research in the middle school students of the three educational institutions under study. This was evidenced by a significant increase in the overall results of the *exit-level test* where Hunzá 10th grade students had an increase of up to 15% and 11th grade students had an increase of 18%. In addition, tenth grade students at St. Simon's showed an increase of 13% and eleventh grade students showed an increase of 11%. The tenth and eleventh grade students at Abraham Lincoln High School, although showing a lower proportion increase, 9 % and 5.9 % respectively, continued to have the highest performances, which is largely due to the competency training presented by students from lower grades.

Regarding the results obtained by the students in each competition in the *exit test*, it is also concluded that, in the three educational institutions, the competence that obtained the highest result was the *UC* competence and, worryingly, the competence that obtained the least result was that of *PRC*, which implies that within science classes there must be more exhaustive and rigorous work to motivate the development of cognitive processes in students, strengthening mental processes such as seriation, discrimination, classification, analysis and synthesis, findings that are in line with the study of Torres, Mora, Garzón and Ceballos (2013). On the contrary, these results are not in line with the progress made by the students when interacting with the laboratory practices.

Regarding the experimental work in the classroom, it can be concluded that the methodology implemented led to the adaptation of practices that were striking and interesting, both for students and for teachers who teach physics in each of the grades in the different educational institutions. In this way, the students interacted with different types of practices (virtual, guided, among others), designed with all kinds of resources. This aspect supported the initial motivation to apply the methodology strategy in different educational contexts, showing results that give a significant scope to the proposal in the field of education, since it provides both teachers and students with tools for the appropriation of scientific competencies in the different science subjects in a dynamic and striking way under different contexts.

Thus, it is expected that the research developed will have a positive impact on science teachers who state that not having the necessary resources or time constitutes a limitation for the implementation of experimental practices. This study also identifies the need for educational reflection, showing that the development of scientific skills should not only focus on solving problems with pencil and paper or the application of written tests inside the classroom, but should also promote spaces that denote a special interest for students such as laboratories (Guerrero, 2011), implementing within them, methodologies that enhance scientific curiosity and appropriate the skills necessary to develop critical thinking and scientific reasoning (Torres, 2010).

Nevertheless, in spite of the excellent results obtained in the research, we found some limitations in the implementation of the proposal, being noteworthy: a) The resistance of some rectors and teachers of educational institutions to which they were invited to participate; and, b) the fear of facing new perspectives in education leaves the teaching enclosed in traditional and daily models, displacing the opportunity to implement new pedagogical alternatives that nourish and strengthen the didactic task.

Finally, although it is recognized that the research methodology is widely used worldwide, in Colombia there are no clearly defined guidelines for its implementation, specifically in laboratory practices in secondary education. In this way, new questions are opened to the possibility of transferring this methodology to other schools, and to the influence of certain variables that can mediate its impact, such as the awareness of schools and teachers about new methodologies and previous experience in actions of educational innovation.

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