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EVALUATION OF SCIENTIFIC COMPETENCIES OF SECONDARY SCHOOL STUDENTS IN THE DOMINICAN REPUBLIC

Evaluación de las competencias científicas de los estudiantes de secundaria de República Dominicana

José Rafael Torres-Valdez
Technological University of Cibao, Dominican Republic
https://orcid.org/0000-0002-8787-5330
jose.torresv@minerd.gob.do

Gabriel Enrique Ayuso-Fernández
University of Murcia, Spain
https://orcid.org/0000-0002-8510-556X
ayuso@um.es

Abstract

Achieving quality education is a priority for the Dominican state, considering the development of competencies as a fundamental component for the formation of citizens with life skills, capable of performing effectively in society. The aim of this research is to assess the levels of scientific competence among secondary school students. To assess the levels of competence, an instrument was applied, developed from validated questionnaires and some items released from the PISA Test. The results obtained in the research show that it is necessary to strengthen methodological processes and other elements associated with the development of scientific competencies, as students perceive themselves as having low levels of mastery and also affirm that activities promoting the development of scientific competencies are rarely carried out in the classroom.

Keywords: competencies, education, learning, science education, scientific method.

Resumen

Alcanzar una educación de calidad es una prioridad para el Estado dominicano, ya que el desarrollo de competencias es un componente fundamental para la formación de ciudadanos con habilidades para la vida, capaces de desempeñarse de forma efectiva en la sociedad. El objetivo de esta investigación es evaluar los niveles de competencias científicas del alumnado de secundaria. Para evaluar estos niveles se aplicó un instrumento, desarrollado a partir de cuestionarios validados y algunos ítems liberados de la Prueba PISA. Los resultados obtenidos en la investigación muestran que es necesario fortalecer los procesos metodológicos y otros elementos asociados al desarrollo de competencias científicas, ya que los estudiantes se autoperciben con bajos niveles de dominio y también afirman que con poca frecuencia se realizan en el aula actividades que promuevan el desarrollo de esas competencias.

Palabras clave: aprendizaje, competencias, educación, enseñanza de las ciencias, método científico.

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1 | Introduction

The achievement of quality education is a fundamental priority for the Dominican State. In this context, competency development is conceived as an essential element in forming citizens with life skills, capable of performing effectively and comprehensively in society.

In recent years, the Ministry of Education of the Dominican Republic (MINERD) has made significant efforts and invested substantial resources to improve the internal efficiency of the educational system (access, retention, promotion, repetition, and dropout). Currently, the country invests 4% of its GDP in education, and the proposed modification of General Education Law 66-97 considers the possibility of increasing this investment to 6% of GDP. Thus, new social expectations demand that the Dominican educational system guarantee universal schooling and offer all students, regardless of their origin, opportunities to live, coexist, be productive, and continue learning (MINERD, 2024). According to Caravaca et al., (2021), in recent years the Ministry of Education of the Dominican Republic has promoted a series of reforms, including the extended school day, the construction and rehabilitation of schools, the hiring of additional teaching staff, curricular reform, technical-professional training and teacher training.

However, achieving universal compulsory education is not just about raising the quality of learning by merely equipping schools with technological resources, as if their availability alone were sufficient to develop the fundamental skills of the 21st century (Amiama-Espaillat & Mayor-Ruiz, 2017). Rather, ensuring positive outcomes for students requires focusing on the factors associated with quality and skill development, such as curriculum, evaluation, resources, pedagogical practices, school organization, and teacher qualifications (Blanco, 2006).

More specifically, today's society demands adequate training in science, requiring educational systems to foster scientific competencies that enable students to engage with, integrate into and transform a society where techno-scientific development has an increasingly important impact (Asencio Cabot, 2017).

In this regard, modern education must promote scientific literacy that allows students to understand Natural Sciences and be able to use them as perceptive, critical and sensible citizens (García-Carmona & Acevedo-Díaz, 2018; Karahan & Roehrig, 2017; Organization for Economic Co-operation and Development [OECD], 2017). This literacy should enable students to reflect, reason and establish connections that help them respond to real-life situations (Mkimbili & Odegaard, 2019) and, consequently, that students can understand the cause and effect of the phenomena that surround them, ask questions about complex problems that affect their future, make predictions and develop their logical part from a scientific point of view.

International organizations such as the OECD, through successive PISA studies, have established different models for assessing scientific competence. These models recognize that, to understand and participate in critical debates on science and technology issues, students need to develop three key scientific sub-competencies, which involve the ability to explain natural phenomena; knowledge and understanding of scientific research; and the ability to interpret and evaluate data and evidence scientifically (OECD, 2017).

Therefore, the main objective of this research is to assess the current level of scientific competence among a group of high school students, representative of District 06-03 of Jarabacoa, Dominican Republic, to assess the need to promote educational improvements for students in this area.

2 | Literature review

Education is the key to raising the quality of life and promoting sustainable development worldwide. In addition to improving people's quality of life, access to inclusive and equitable education fosters the acquisition of the necessary tools to develop innovative solutions to the world's biggest problems, as stated by the United Nations (2018) in the 2030 Agenda and the Sustainable Development Goals, where goal 4.1 of SDG 4 is aimed at ensuring that by 2030 all boys and girls complete primary and secondary education, which must be free, equitable and of quality while producing relevant and effective learning outcomes.

United Nations Educational, Scientific, and Cultural Organization (UNESCO, 2017) states that a fundamental change is needed in how we view the role of education in global development, because now more than ever, education is responsible for keeping pace with the challenges and aspirations of the 21st century, promoting the development of skills and competencies necessary to be able to function efficiently in society; in this sense, scientific competencies are important on personal, social and professional levels because through them critical thinking, teamwork, problem solving, creativity and innovation are strengthened (Guzmán Duque et al., 2019).

Quality education promotes action-oriented training and proposes to educate competent individuals to recognize the challenges of their time and the world in which they live, understanding the environmental, economic and social dimensions of sustainable development, in order to intervene in favor of its resolution. Education is a fundamental right and the basis of progress in any country (UNESCO, 2014). This requires a transformation in curricula, so that they can guarantee that all children and young people not only learn basic skills but also develop transferable skills, such as critical thinking, problem solving, activism and conflict resolution, to help them become responsible global citizens (UNESCO, 2017).

Contemporary educational processes must foster the development of scientific competencies in students, enabling them to understand, adapt to and interpret the changing world, transforming their social, economic and environmental reality (Corredor & Saker, 2018). Therefore, secondary education must focus its efforts on the implementation of science teaching and learning processes, from a scientific competency approach (Fuentes et al., 2019; Pérez & Meneses Villagrá, 2020).

Based on this reality, the need to transform educational processes is evident, considering that technological advances require the development of scientific thinking through which students can access and transform their environment. All this requires teaching updated, contextualized and engaging science that sparks student interest and emphasizes the development of scientific competencies, considering that the particular context of each country will allow for the generation of adequate guidance for the development of competencies (Muñoz Martínez & Charro Huerga, 2023).

The lack of student motivation in the scientific field is increasingly evident. Rocard et al. (2007) identified that one of the reasons why young people do not develop interest in science is the presentation of programs far removed from the reality of students, with a conceptual approach and an approach to knowledge in an abstract way, that lacks support from observation and experimentation and neglects a direct connection with current situations and their social implications (Aguirregabiria Barturen, 2023). Likewise, the use of active methodologies focused on scientific research and problem solving is limited, leading to disciplines being perceived as uninteresting, complicated and disconnected from everyday life.

2.1. Concept of Scientific Competence Assumed in Research

Educational systems around the world are under constant pressure to renew themselves in order to adapt to the demands of today's society, which requires individuals with the skills and abilities to perform effectively.

In this context, competencies are identified as one of the basic elements that underpin the educational curriculum of the school system (Rodríguez Martínez & Gutiérrez, 2014). Therefore, since social reality is dynamic and change is accelerating, the educational system as a whole must assume the responsibility of addressing the training needs of the society in which it is immersed (Córica, 2020). In this sense, providing a quality education that fosters the development of scientific competencies is a necessity of today's society and a commitment of schools as training institutions.

The term «competence» has a long tradition dating back to the major currents of the second half of the 20th century. In the 1960s, the term was introduced in education as part of the objective assessment of learning. The competency approach became popular in the United States around 1970 through the competency-based professional training movement for teachers. In the case of the Dominican Republic, the incorporation of competencies into education is more recent; it was in 2013 that a competency-based curriculum was implemented. These competencies are defined as the ability to act effectively and autonomously in diverse contexts by mobilizing concepts, procedures, attitudes, and values in an integrated manner (MINERD, 2023).

From a scientific perspective, competencies focus on the relevance and applicability of learning. In this research, the evaluated scientific competencies are based on those established by the OECD (2017) for 15-year-old secondary school students with their definitions described by the OECD.

a. Explaining phenomena scientifically: Skills that enable one to recognize a problem (identify the reason why an object or phenomenon is being studied, determine the factors that affect its behavior) and formulate questions for investigation.

b. Interpreting data and evidence scientifically: The ability to describe and explain the results or data obtained in an investigation, in addition to identifying the relationships between variables in a data table.

c. Evaluating and designing scientific research: Ability to select an appropriate experimental design to test a previously stated hypothesis, in addition to identifying the dependent, independent and controlled variables.

Table 1 describes the components associated with scientific competencies, assessed in the PISA tests, under the OECD guidelines and the elements or operations characteristic of each of them.

Table 1. Scientific competencies assessed in PISA

1. Explain phenomena scientifically
1a. Recall and apply appropriate scientific knowledge. 1b. Identify, use and generate explanatory models and representations. 1c. Make and justify appropriate predictions. 1d. Offer explanatory hypotheses. 1e. Explain the potential implications of scientific knowledge for society.
2. Interpret data and evidence scientifically
2a. Transform data from one representation to another. 2b. Analyze and interpret data and draw relevant conclusions. 2c. Identify assumptions, evidence and reasoning in science-related texts. 2d. Distinguish between arguments based on scientific theory and evidence and those based on other considerations. 2e. Evaluate scientific arguments and evidence from various sources (e.g., newspapers, the Internet, magazines).
3. Evaluate and design scientific research
3a. Identify the question explored in a given scientific study. 3b. Distinguish issues that could be investigated scientifically. 3c. Propose a method to scientifically explore a given question. 3d. Evaluate methods to scientifically explore a given question. 3e. Describe and evaluate how scientists ensure the reliability of data, as well as the objectivity and generalizability of explanations.

Note: Source OECD. (2017). PISA Assessment and Analysis Framework for Development: Reading, Mathematics and Science.

Different studies have shown that, throughout the years of compulsory secondary education, students develop little ability to understand the meaning of the scientific research analyzed (Dori et al., 2018). The difficulties detected among secondary school students in scientific research skills include identifying the main problem in an investigation, constructing hypotheses, drawing conclusions or proposing an experimental design. Difficulties that persist throughout the entire educational stage (Ayuso Fernández et al., 2022).

2.2. The Dominican Republic in the PISA studies

The results of the PISA (Program for International Student Assessment) tests have shown significant challenges for the Dominican Republic compared to other participating countries. PISA assesses the performance of 15-year-old students in reading, mathematics and science, and provides international comparative data on the quality and equity of education.

Overall, the Dominican Republic has struggled to achieve expected proficiency levels in these areas, with scores below the OECD (Organization for Economic Co-operation and Development) average and those of other Latin American and Caribbean countries. Test results have shown significant gaps in academic performance between Dominican students and their peers from other countries. Although the country has improved its PISA test results in 2022 compared to 2015 and 2018, performance levels remain very poor compared to other countries (OECD, 2023).

Around 23% of students in the Dominican Republic reached level 2 or higher in science, while the OECD average is 76%. The requirements for this level are that, at a minimum, these students can recognize the correct explanation of familiar scientific phenomena and use this knowledge to determine, in simple cases, whether a conclusion is valid based on the data provided. Another aspect to highlight is that, in the Dominican Republic, almost no students were deemed competent, with the OECD average being equivalent to 7%. This level of mastery implies that students can creatively and autonomously apply their knowledge of and about science to a wide variety of situations, including unfamiliar ones (OECD, 2023). In addition, compared to previous editions of the PISA science test, the study shows that the performance of the Dominican Republic has not varied significantly (Cruz & Mones, 2019), placing the country among the lowest performers in this discipline.

According to Thompson et al. (2018), the above results may be linked to factors such as inequalities due to economic income levels, geographic area and type of educational institution, as well as the country's high rates of school absenteeism, lack of educational materials and absence of quality teacher professional development.

However, according to González-Mayorga (2023), the results of PISA in the Dominican Republic contribute to fueling the debate around the quality of its educational system and, in doing so, fulfill one of the OECD's major objectives: empowering countries to promote significant educational reforms and transformations that guarantee the quality of processes and the development of life skills in students.

3 | Methodology

The aim of this study is to describe and analyze the data collected to identify patterns, trends and differences between groups to answer specific research questions and generate knowledge that may be useful for decision-making in the educational field. Consequently, this is a descriptive and comparative study of a quantitative nature. Information has been collected from a representative population of students through a knowledge questionnaire, and the results obtained are statistically analyzed based on specific variables, such as each student's grade, age, gender or whether they belong to public or educational agreement centers.

The socio-educational context where this evaluation program is implemented corresponds to the municipality of Jarabacoa, an area comprising 20 educational centers offering secondary education. Of these, 15 belong to the public sector (in terms of management and financing) and 5 operate by agreement (private management and public financing).

To assess the scientific competency levels of high school students, a questionnaire was administered and validated based on the works of Cordón et al. (2009) and Franco et al. (2021), among others, and incorporating various items from the PISA Test. The population under study consists of 2,010 students from the second cycle of secondary school, from which a sample of 324 students was selected, with a sampling error of 5% and a confidence level of 95%. The selected students are from the fourth, fifth and sixth year of high school, and they belong to two public educational centers and two agreement centers in educational District 06-03 of Jarabacoa, with the characteristics described in Table 2.

Table 2. Characteristics of the student sample

Feature	Classification	Percentage
Type of educational center	Public	48%
	By agreement	52%
Sex	Male	33%
	Female	67%
Age	15 years	16%
	16 years old	25%
	17 years old	38%
	18 years old	17%
	Over 18	4%

(Continuation)

Feature	Classification	Percentage
Grade	Fourth	31%
	Fifth	30%
	Sixth	39%

Note. n=324

The data collected through the questionnaire were sorted, tabulated and graphed with Excel and statistically analyzed using the Jamovi program (Version 2.3.21).

3.1. Characteristics of the questionnaire applied to students

The scientific competencies assessed by the questionnaire were: explaining phenomena scientifically, interpreting data and evidence scientifically, and evaluating and designing scientific research.

According to the provisions for the assessment of scientific competence in the PISA studies (OECD, 2017), a scientifically educated person can engage in a reasoned discourse on science, sustainability and technology to take action. Thus, the items selected for the assessment of scientific competence consisted of 6 different questions, with multiple-choice answers (only one correct answer). In addition, the assessment was complemented with the presentation of a problematic situation related to the design of an experiment and another question related to the interpretation of data from a table; these latter two, with open answers. In addition to assessing competence levels, the questionnaire included personal questions regarding students' perceptions of their mastery of scientific competencies and how these are promoted in the classroom.

Table 3 presents a description of the items corresponding to each competency evaluated, which are characterized by being multiple choice, with only one correct answer.

Table 3. Multiple-choice items and assessed scientific competence

No.	Items	Competence
3	What types of diseases can people be vaccinated against?	Explain phenomena scientifically
4	If animals or people suffer from a bacterial infectious disease and then recover, the type of bacteria that caused the disease usually does not infect them again. What is the reason for this?	
1	Among the statements presented, which one is supported by the data in the figure on sugar consumption and number of cavities in different countries?	Interpreting data and evidence scientifically
5	The following figures represent the average wind speed at four different locations over the course of a year. Which figure indicates the most appropriate location for installing a wind turbine?	
2	A country has a high number of cavities per person. Which question about tooth decay could be answered with the help of a scientific experiment?	Evaluate and design scientific research
6	The effectiveness of nicotine patches to stop smoking is to be determined. What is the best experimental design to test the effectiveness in a group of 100 smokers?	

Note: The items used were adapted from questions released by PISA.

Table 4 presents the open-ended question items corresponding to situations related to the design of experiments and the interpretation of tables.

Table 4. Open-ended questions on interpreting tables and designing experiments

No.	Items	Competence
7a	Write the scientific problem that is attempted to be solved in an experiment, in which 20 seeds were placed in five pots with the same humidity, soil and lighting, but different temperatures.	Evaluate and design scientific research
7b	Write a hypothesis for an experiment in which 20 seeds were placed in five pots with the same humidity, soil and lighting, but different temperatures.	
7c	Write the conclusion that can be deduced from the germination results of an experiment in which 20 seeds were placed in five pots with the same humidity, soil and lighting, but different temperatures.	
7d	Design an experiment to find out how humidity influences seed germination.	

(Continuation)

No.	Items	Competence
8a	Write the variables represented in a table where the age and weight of 6 people are presented.	**Interpreting data and evidence scientifically**
8b	Build a figure to represent the data in a table where the age and weight of 6 people are presented.	
8c	What title would you give to a figure that contains the age and weight data of 6 people?	
8d	What conclusion can you draw from the data in the table showing the age and weight of 6 people?	

Note: The items were adapted from Cordón et al. (2009)

In order to understand the students' perception regarding mastery in designing experiments using the scientific method—and the frequency with which experiments and scientific practices are carried out in the classroom—11 personal assessment items were designed, as presented in Table 5.

Table 5. Personal assessment items

No.	Items
1a	What is your level of knowledge on the representation and interpretation of tables and figures?
1b	What is your level of knowledge about hypothesis formulation?
1c	What is your level of knowledge in identifying the variables of an investigation?
1d	What is your level of knowledge in designing and evaluating experiments?
2a	How often are practice and experiments carried out in science classes?
2b	How often is the scientific method and problem solving applied in science classes?
2c	How often are tables and graphs used in science classes?
3	Do you know the meaning of the term "variable"?
4	Do you remember having developed activities in class in which you had to express hypotheses?
5	Which phrase means the same as hypothesis?
6	What do you understand by the expression «experimental design»?

3.2. Comparative statistical analysis

For the comparative analysis, the answers were grouped according to the three evaluated competencies: Explaining phenomena scientifically (EFS), Interpreting data and evidence scientifically (IDES), Evaluating and designing scientific research (EDSR). To do this, the answers to the two questions for each competency were summed, as shown in Table 2.

Additionally, the significance of differences among participants—classified by their grade level (4^{th}, 5^{th} and 6^{th} year of secondary school) and by the type of educational center (with centers C1 and C2 being public and C3 and C4 being agreement centers)—was calculated.

To determine whether there are statistically relevant differences between two or more groups of an independent variable, the non-parametric Kruskal-Wallis test was used, allowing us to analyze differences among the three secondary school grades.

To statistically compare the means and determine whether there is a difference in the dependent variable between two independent groups, the Mann-Whitney U test was used. This test shows whether the distribution of the dependent variable is the same for the two groups and, therefore, whether they come from the same population when comparing public and agreement centers.

4 | Results

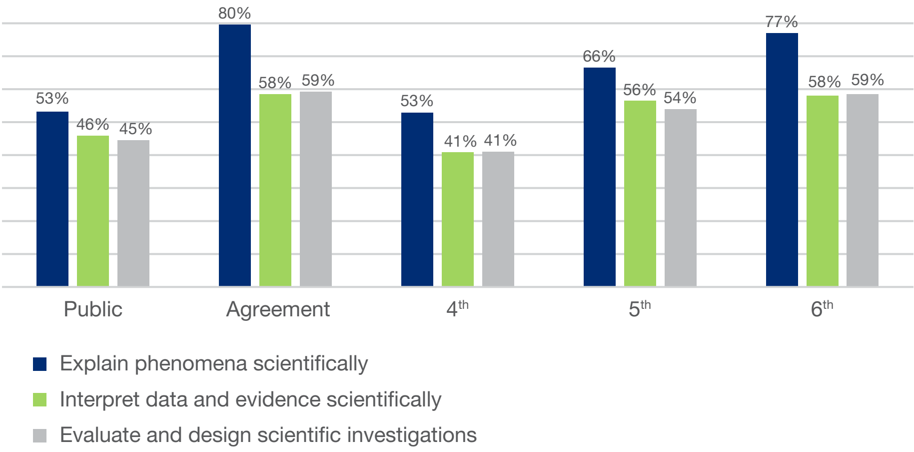
4.1. Level of scientific competence in multiple-choice questions

As a result of the statistical analyses, significant differences are seen between public and agreement centers, as well as among the 4^{th}, 5^{th} and 6^{th} academic grades. In this sense, the results are presented below, differentiated by the type of center and the academic grade of the students.

Figure 1 shows the percentages of correct answers obtained by students from public and agreement centers for each assessed competency, according to the summary of questions in Table 2. The data in Figure 1 indicate that agreement centers have higher levels of mastery in the three competencies; for example, in explaining phenomena scientifically, agreement centers achieve 80% correct answers compared to 53% in public centers. However, in general, mastery levels are low in both public and agreement centers, as only in the competency of explaining phenomena scientifically do agreement centers exceed 60% correct answers.

Regarding the percentages of correct answers obtained by 4th, 5th and 6th grade students for each competency, all data in Figure 1 indicate that 6th grade students have higher levels of mastery in all three competencies. For example, in explaining phenomena scientifically, 6th-grade students have 77% correct answers compared to 53% and 66% of 4th and 5th-grade students, respectively. Nevertheless, overall mastery levels remain low for all grades.

Figure 1 | Levels of scientific competence of students



Note. n=324

4.2. Level of scientific competence in open questions

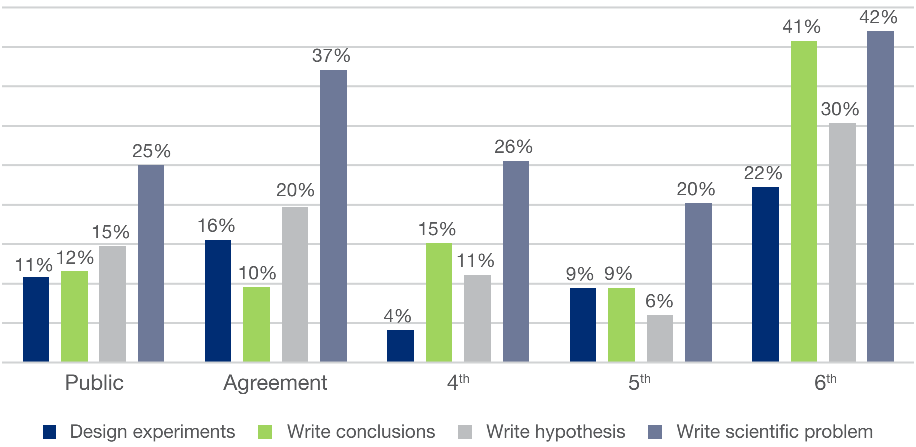
Figure 2 shows the percentages of correct responses for four open questions related to evaluating and designing scientific research (Table 3, questions 7a-7d).

According to the data in Figure 2, the agreement centers present higher percentages of correct answers for questions related to designing experiments (16% in agreement centers vs. 11% in public centers), writing hypothesis (20% vs. 15%), writing scientific problems (37% vs. 25%). However, regarding writing conclusions, public centers exceed agreement centers by 2% (12% vs. 10%).

Regarding academic grades, 6th grade students show higher percentages of correct answers than 4th and 5th grade students for all four questions related to designing experiments, writing hypotheses, writing scientific problems, and writing conclusions.

Overall, in both public and agreement centers, the percentage of correct answers does not exceed 37% for any of the questions related to evaluating and designing scientific research, across all three grades, it does not exceed 42%.

Figure 2 | Competence to evaluate and design scientific research



Note. n=324

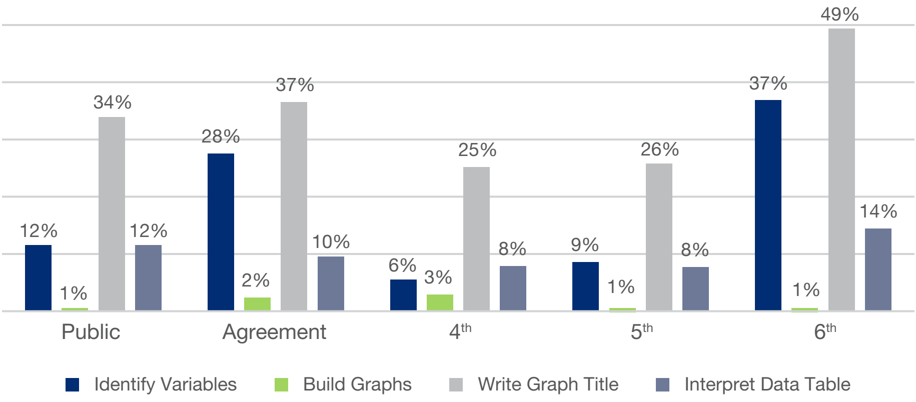
Figure 3 shows the percentages of correct responses for four open questions related to interpreting scientific data and evidence (Table 3, questions 8a-8d).

According to the data in Figure 3, agreement centers present higher percentages of correct answers for the questions related to identifying variables, constructing graphs and placing a graph title.

By academic grade, the data indicate that 6th-grade students have higher percentages of correct answers than 4th and 5th-grade students for questions related to identifying variables, writing graph titles, and interpreting data tables, although 4th-grade students outperformed 6th-grade students in constructing graphs.

Overall, in both public and agreement centers, the percentage of correct answers does not exceed 37% for any question related to interpreting scientific data and evidence, and across all grades it does not exceed 49%.

Figure 3 | Competence: Interpreting scientific data and evidence



Note. n=324

4.3. Students' self-perception of their level of scientific competence

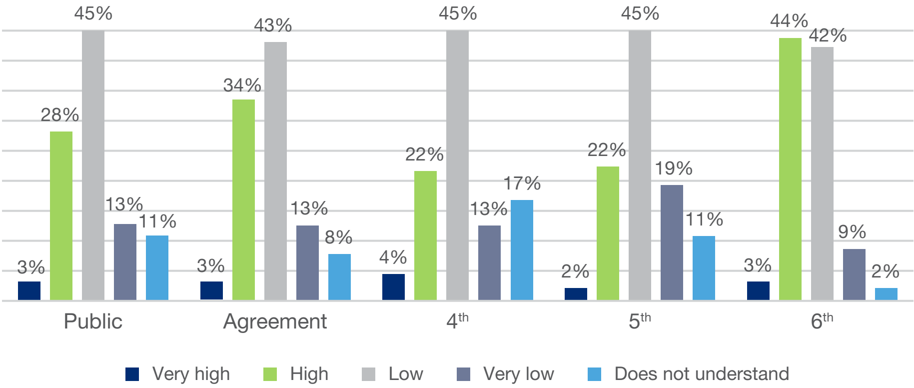
This section presents the results of the personal assessment questions, regarding students' perceptions of their mastery of scientific competencies and the frequency with which they carry out practical activities aimed at promoting these competencies.

Figure 4 shows the results of the students' self-assessment of their mastery in interpreting tables and graphs.

According to Figure 4, 58% of students from public schools and 56% from partner schools report having low or very low levels of mastery in interpreting tables and graphs.

By academic level, 51% of 6th-grade students, 64% of 5th-grade students, and 58% of 4th-grade students report low or very low mastery in this area.

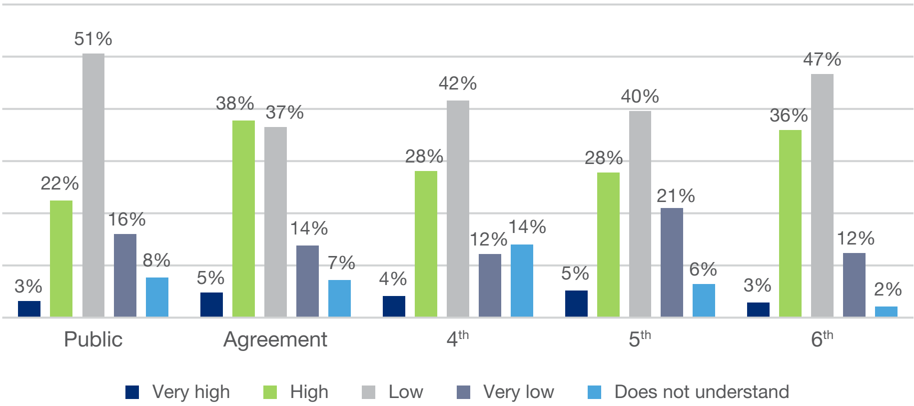
Figure 4 | Mastery rating for: Interpreting tables and graphs



Note. n=324

Regarding their level of mastery in formulating hypotheses, Figure 5 shows that 67% of students from public schools and 51% from agreement schools report having low or very low mastery in this field. By academic grade, 59% of 6th-grade students, 61% of 5th-grade students, and 54% of 4th-grade students report low or very low mastery in formulating hypotheses.

Figure 5 | Assessment on domain for: Hypothesizing

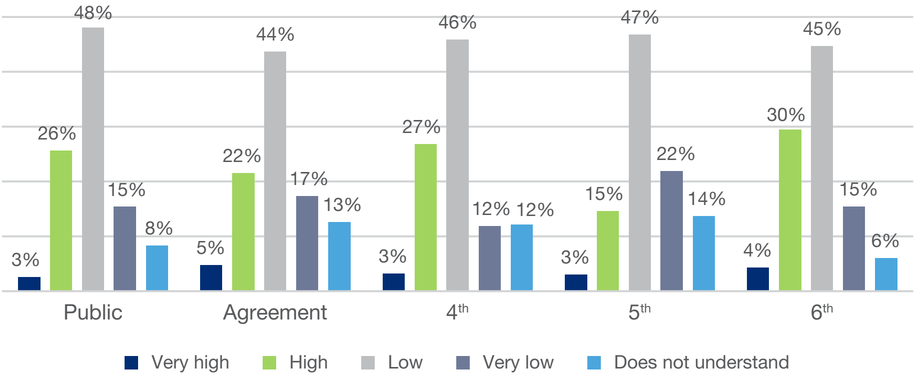


Note. n=324

Figure 6 shows that 63% of students from public schools and 61% from agreement schools report low or very low mastery in identifying variables.

By academic grade, 60% of 6th-grade students, 69% of 5th-grade students, and 58% of 4th-grade students indicate low or very low mastery in this area.

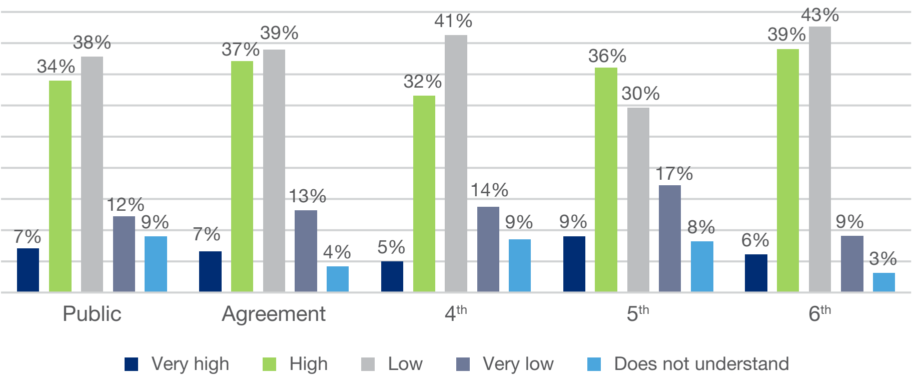
Figure 6 | Assessment on the domain for: Identify variables



Note. n=324

Figure 7 shows that 50% of students from public schools and 52% from charter schools report low or very low mastery in evaluating and designing experiments. By academic grade, 52% of 6th-grade students, 47% of 5th-grade students, and 57% of 4th-grade students indicate low or very low mastery in this area.

Figure 7 | Assessment on the domain for: Evaluating and designing experiments

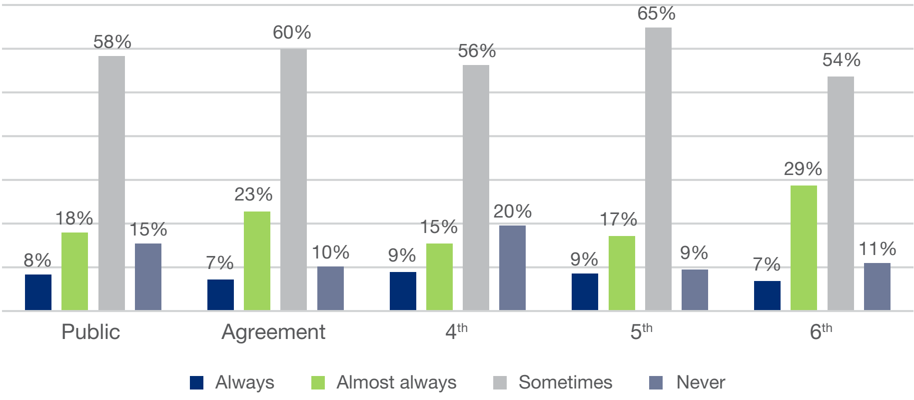


Note. n=324

Figure 8 shows the results of students' assessment of the frequency with which experiments are carried out. Overall, 73% of students from public centers and 70% from agreement centers report that experiments are sometimes or never conducted in the classroom.

By academic grade, 65% of 6th-grade students, 74% of 5th-grade students, and 76% of 4th-grade students indicate that experiments are only sometimes or never conducted in class.

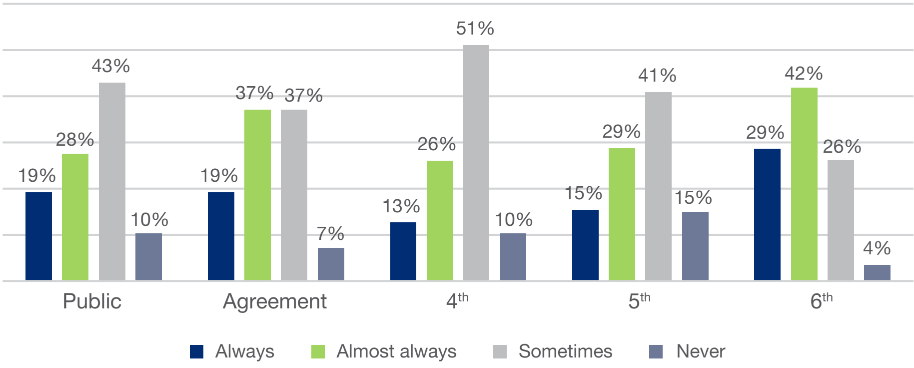
Figure 8 | Frequency assessment of: Conducting experiments



Note. n=324

Figure 9 shows that 53% of students in public schools and 44% in charter schools report that the scientific method is used only sometimes or never in classes. By academic grade, 30% of 6th-grade students, 56% of 5th-grade students, and 61% of 4th-grade students indicate that the scientific method is used only sometimes or never in classes.

Figure 9 | Frequency rating of: Use of the scientific method



Note. n=324

5 | Discussion of results and conclusions

When carrying out a comparative analysis between the percentages of correct answers, for the open question related to interpreting data tables, as shown in Figure 3, both in public and agreement centers, the average percentage of correct answers is barely 11%. This aligns with the results from the personal assessment of students' self-perceived mastery of interpreting tables and graphs, as shown in Figure 4, where 58% of students from public centers and 56% from agreement centers report having low or very low levels of mastery in this skill.

These findings are consistent with those of a study on the graphical comprehension of secondary school students by García et al. (2020), in which only 5.1% of students formulated explanatory hypotheses about data behavior. According to the authors, these results suggest potential weaknesses in the type of tasks presented in primary education textbooks or those proposed by teachers.

Regarding the comparison of correct answer percentages for the open-ended question on identifying variables, as shown in Figure 3, both in public and in agreement centers, the average percentage of correct answers is 20%. This corresponds with the results of the personal assessment question on students' self-perceived mastery of identifying variables, as shown in Figure 6, where 63% of students from public centers and 61% from agreement centers report having low or very low levels of mastery in this area. These findings align with the research conducted by Lerma et al. (2023), which concluded that students struggle with identifying variables in experiments or problem situations and often fail to understand the concept of a variable. In addition, students show weakness in formulating or proposing questions for an experiment.

In terms of experiment design, the results in Figure 2 show that, on average, only 13.5% of the students from public and charter schools correctly answered the question related to designing experiments. This is consistent with the findings in Figure 7, where 50% of the students from public schools and 52% from charter schools report having low or very low levels of mastery in evaluating and designing experiments. Similarly, Figure 8 shows that 73% of the students from public schools and 70% from charter schools report that experiments are sometimes or never conducted in the classroom. Furthermore, Figure 9 indicates that 53% of the students from public schools and 44% from charter schools state that the scientific method is used only sometimes or never in their classes.

These findings align with Rasilla (2004), who emphasized the importance of students learning to do science in educational settings through the appropriate application of the scientific method, experimentation and scientific research within the school context.

Regarding the comparative analysis of results related to the open-ended question on writing hypotheses, Figure 2 shows that, on average, only 17.5% of students from public and agreement centers correctly formulated a hypothesis based on the given situation. This aligns with the results in Figure 5, where 67% of students from public centers and 51% from agreement centers report having low or very low levels of mastery in formulating hypotheses.

In this context, Acevedo et al. (2020) highlight the need to focus science education on developing scientific skills, such as hypothesis formulation. This skill helps students critically understand the world and enhances other cognitive processes, such as observation, description, classification, and questioning.

For the multiple-choice questions, where students analyzed various issues related to explaining scientific phenomena, evaluating and designing scientific research and interpreting data and evidence scientifically, Figure 1 shows better results than the open-ended questions in figures 2 and 3. In the latter, students had to identify variables, write graph titles, interpret data tables, construct graphs, design experiments, write hypotheses, formulate scientific problems, and draw conclusions.

However, despite higher percentages of correct answers in multiple-choice questions compared to open-ended questions, overall mastery levels remain low in both public and charter schools. Only in the competence of explaining scientific phenomena do charter schools show a correct answer rate above 60%. These findings are consistent with the study by Cruz-Pichardo (2021), which concluded that Dominican students face difficulties in analyzing, formulating and solving problems.

Therefore, it is essential to strengthen the methodological approaches through teacher training and updates in the use of new teaching techniques and strategies focused on research, problem-solving, and utilizing contextual resources as educational tools. These measures are crucial for developing scientific competencies in secondary school students in educational District 06-03 of Jarabacoa. This reality may extend to secondary school students more broadly as evidenced by the low percentages of correct answers, students' self-perceived low mastery of scientific competencies, and their assessment of the infrequency of classroom activities aimed at fostering these competencies. Additionally, aligning science curricula with contemporary societal demands and challenges is necessary to provide students with a solid scientific education (Zompero et al., 2022).

Educational research consistently emphasizes that one of the primary objectives of science education is to equip all citizens with a foundational scientific literacy that enables them to apply their scientific knowledge in daily life and make informed judgments about scientific and technological issues (Ferreira & Morais, 2018).The weaknesses in scientific competences among secondary school students highlight the need to focus on other key aspects, such as teacher training and updating, instructional methodologies and assessment strategies. These elements must be reviewed to transform pedagogical processes, enabling science education that extends beyond the classroom and fosters essential life skills. A comprehensive review of educational programs is recommended, including the curricula of teacher training institutions, the selection and integration of new teachers into the educational system, and the ongoing professional development of current educators.

In conclusion, innovation in science teaching is essential to promote the development of scientific competencies among students. In many cases, science instruction reduces the scientific method to a formulaic approach, requiring students to follow a set of steps and memorize isolated concepts without contextual relevance (Chamizo & Izquierdo, 2007). Therefore, it is necessary to implement student-centered methodologies that emphasize scientific research as a means to address real-world problems within the school context. This approach can foster students' curiosity and interest in science while demonstrating the connection between various scientific concepts and the essential skills they need to develop (Muñoz Martínez & Charro Huerga, 2023).

Author contributions

Conceptualization: T. J., A. G.; methodology: T. J., A. G.; software: T. J., A. G.; validation: T. J., A. G.; formal analysis: T. J., A. G.; investigation: T. J., A. G.; resources: T. J.; data curation: T. J., A. G.; writing (original draft): T. J.; data curation: T. J., A. G.; writing: T. J., A. G.; writing (original draft): T. J.; writing (proofreading and editing): T. J.; visualization: T. J.; supervision: A. G.; project administration: A. G.

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