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Artículos científicos

¿Cómo viaja la luz? La actividad experimental para desarrollar competencias científicas en la infancia

How Does Light Travel? The Experimental Activity to Develop Scientific Competencies in Childhood

Como a luz viaja? Atividade experimental para desenvolver habilidades científicas na infância

Claudia Carolina García Gaitán
Universidad Pedagógica Nacional Unidad 241, México
garcia.claudia@upnslp.edu.mx
https://orcid.org/0000-0003-3799-7249

Mario Humberto Ramírez Díaz
Instituto Politécnico Nacional, México
mramirezd@ipn.mx
https://orcid.org/0000-0002-3459-2927

Carlos Adrián Arriaga Santos
Universidad Politécnica de San Luis Potosí, México
carlos.arriaga@upslp.edu.mx
https://orcid.org/0000-0003-1356-406X

Resumen

En México, en el nivel de primaria se espera que los estudiantes comprendan fenómenos físicos, entre los que se encuentra la luz y sus interacciones. Esto representa un desafío debido a que, durante la formación inicial docente, los contenidos alusivos a la física no están incluidos en el mapa curricular. Las implicaciones se observan en el aprendizaje de los estudiantes de este nivel, porque les es complejo explicar desde la perspectiva científica los fenómenos y procesos naturales. El objetivo de esta investigación fue analizar el nivel de logro de la competencia: comprensión de fenómenos y procesos naturales desde la perspectiva científica, mediante la aplicación de una actividad experimental relacionada con la trayectoria de la luz. Se trató de un estudio de caso, a través de un enfoque cualitativo. Los participantes fueron 59 alumnos de 8 a 10 años de edad que cursan el nivel de educación primaria. En los resultados se reconoce la necesidad de la actividad experimental para promover el desarrollo de competencias científicas en la infancia. La importancia de favorecer la reflexión de la observación para la construcción de explicaciones de lo que ocurre en el entorno y la construcción de significados para el conocimiento científico.

Palabras clave: actividad experimental, competencia científica, enseñanza de las ciencias, fenómenos de luz.

Abstract

At the elementary level in Mexico, students are expected to understand physical phenomena, including light and its interactions. This represents a challenge because, during initial teacher education, content related to physics is not included in the curriculum map. The implications are observed in the learning of students at this level, because it is complex for them to explain natural phenomena and processes from a scientific perspective. The objective of this research was to analyze the level of achievement of the competency: understanding of natural phenomena and processes from a scientific perspective, through the application of an experimental activity related to the trajectory of light. It was a case study, using a qualitative approach. The participants were 59 students between 8 to 10 years of age in elementary school. The results recognize the need for experimental activity to promote the development of scientific competencies in children. The importance of favoring the reflection of observation for the construction of explanations of what happens in the environment and the construction of meanings for scientific knowledge.

Keywords: experimental activity, scientific competence, science education, light phenomena.

Resumo

No México, no nível elementar, espera-se que os alunos compreendam fenômenos físicos, entre os quais a luz e suas interações. Isso representa um desafio, pois, durante a formação inicial de professores, os conteúdos relacionados à física não constam no mapa curricular. As implicações são observadas na aprendizagem dos alunos deste nível, pois é complexo para eles explicar fenômenos e processos naturais a partir de uma perspectiva científica. O objetivo desta pesquisa foi analisar o nível de realização da competência: compreensão de fenômenos e processos naturais a partir de uma perspectiva científica, por meio da aplicação de uma atividade experimental relacionada ao caminho da luz. Tratou-se de um estudo de caso, por meio de uma abordagem qualitativa. Os participantes foram 59 alunos de 8 a 10 anos de idade que frequentam o ensino fundamental. Os resultados reconhecem a necessidade de atividade experimental para promover o desenvolvimento de habilidades científicas na infância. A importância de favorecer a reflexão da observação para a construção de explicações sobre o que acontece no ambiente e a construção de significados para o conhecimento científico.

Palavras-chave: atividade experimental, competência científica, ensino de ciências, fenômenos de luz.

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Introduction

The term competence, according to Tobón (2013), refers to a series of complex processes through which individuals put into action knowing how to be, knowing how to know and knowing how to do. From the perspective of the Mexican educational model, it is attributed to an ability to respond to diverse situations by putting skills, knowledge and attitudes into practice. During primary education, a competency approach is pursued, which prioritizes the mobilization of knowledge in the student's daily life.

A scientific competence is defined by the Organization for Economic Co-operation and Development [OECD] (2006) for the purposes of the Program for International Student Assessment (PISA) in the following terms:

> Scientific knowledge and the use made of that knowledge to identify issues, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions on science-related topics; understanding of the characteristic features of science, understood as a form of knowledge and human research; awareness of the ways in which science and technology shape our material, intellectual and cultural environment; the willingness to engage in science-related matters and to engage with the ideas of science as a thoughtful citizen (p. 23).

Training in scientific skills makes it possible to use what has been learned to solve problems in everyday situations (Castro and Ramírez, 2013), in addition to building knowledge and putting it into practice to interpret the natural phenomena that occur in the environment, which entails the student to raise questions, investigate and formulate explanations. Adúriz (2017) proposes the "three C's model" to define school scientific competence as any ability to perform an action related to curricular scientific content, within a particular educational context.

The Mexican curriculum refers to the development of three competencies for basic scientific training: a) understanding of natural phenomena and processes from a scientific perspective; b) informed decision-making for the care of the environment and health promotion oriented to the culture of prevention, and c) understanding of the scope and limitations of science and technological development in various contexts. These have a close relationship with the expected learning of the current educational model, which seeks from a comprehensive perspective to respond to the objectives of science education, which implies knowing science and about science. (Adúriz, 2018).

In Mexico, during primary education, the study of science is developed from the training field of "Exploration and understanding of the natural and social world", constituted by the approaches of biology, physics, chemistry, as well as social, political, economic, cultural and ethical (Secretariat of Public Education [SEP], 2017). The purpose is to promote knowledge of what happens in the student's environment through interaction with their family, school and community; in addition, the development of habits for a healthy life. This training field, through the study of science, aims to promote participation in the preservation of the environment, understand physical phenomena, recognize the properties of materials and the transformation they undergo in daily activities.

Another of the purposes of science, at the primary level, is to develop the ability of critical thinking in children from the study of natural phenomena, the exploration and understanding of scientific activities. However, the substantive intention concerns the formation of a democratic citizenry for reasoned decision-making and the construction of a sustainable future, which alludes to the epistemology of science (Acevedo, 2008). The foregoing forms one of the characteristics of the social value of scientific knowledge from which it is sought to promote at an early age a conscious and supportive act regarding the well-being of society (Fumagalli, 2013).

Based on this background, the following question arises that guided this research: to what extent is the understanding of natural phenomena and processes developed from a scientific perspective through the application of an experimental activity related to the path of light as a study? of case? And consequently, the objective of this research is as follows: to analyze the level of achievement of the competence to understand natural phenomena and processes from a scientific perspective through the application of an experimental activity related to the path of light as a case study.

The teaching of science in primary education

We are surrounded by natural phenomena: the sunset, the formation of clouds, the rain, the birth of a plant, the fall of the leaves... However, if we were to question why it rains, or why the clouds do not fall, or why there is night and day, the answer would hardly have scientific support. With the exception of those who are dedicated to the study of science, the explanation would be in colloquial terms and based on assumptions and inferences that have been acquired throughout the particular experience of each individual. In particular, children use prior ideas to explain observations and events that occur in their environment; of course, compared to an adult, they have fewer concepts (Harlen & Qualter, 2004). Therefore, it is important to promote school science training from an early age that contributes to the development of knowledge, skills and attitudes (Weissmann, 2013).

The study of science at an early age implies that children use previous ideas, obtained through experiences, to explain observations and events in order to understand their environment and achieve the assimilation of new knowledge resulting from social interaction (Harlen and Qualter, 2004). It requires the implementation of curiosity to trigger a series of questions that motivate inquiry (Rodríguez, Cáceres and Franco, 2021). For this, a teaching aimed at favoring basic scientific training is necessary.

On the other hand, science teaching represents a complex process for teachers at the primary level due to a series of factors. The first corresponds to the lack of mastery and updating of the contents related to science, since during initial training there is an absence of disciplinary study (Weiss, Block, Civera, Dávalos and Naranjo, 2019), which generates complexity when attending and even identify doubts and misconceptions of children (Weissmann, 2013). The second refers to a smaller amount of resources suggested for the study of science compared to the materials created for reading, writing and arithmetic. Consequently, the prevailing didactics corresponds to the use of proposals characterized, for the most part, by the reproduction of information, or the exclusive use of the textbook as a resource for teaching, although these materials rarely consider issues associated with the development of scientific competence (Laya and Martínez, 2019).

However, the purpose is to promote the understanding of natural phenomena based on the interactions of students, teachers and knowledge (Alves, 2018). This implies using a series of strategies that lead to the development of scientific knowledge from an early age (Pozo and Gómez, 2006). Likewise, a critical scientific literacy for collective action and the common good of society (Porlán, 2018).

Experimental activity to develop scientific skills

The experimental activity is a strategy that contributes to the understanding of phenomena, awakens the need to explain why the observed events occur, which allows the student to build school scientific knowledge (Fumagalli, 2013). Experimentation in science education represents an opportunity for the manipulation of various physical and natural events; promotes interaction in the classroom, the development of skills and attitudes associated with science in a dynamic and realistic way (Arce, 2002). In this sense, it is necessary to go beyond just demonstration and execution and achieve reflection that leads to the achievement of scientific competencies.

Experimental activities favor the development of scientific thought and offer the possibility of increasing experiences. Likewise, they generate research processes that put observation into practice, ask questions, make predictions and confront ideas, which will allow the construction of different explanatory perspectives of the phenomena studied (Amelines and Romero, 2017). They are a strategy that makes it possible to incorporate information and develop habits of thinking and reasoning.

During these types of activities, it is necessary to provide spaces for the socialization of predictions and inferences that were built from experimentation adapted to the student's daily life (Castro and Ramírez, 2013). Observation and recording are essential to arouse curiosity, promote understanding of the various phenomena, the consequences of their alteration and impact; In addition, they open the door to formulate solutions to problematic situations in the context (García and Moreno, 2020). In short, it is about stimulating communication skills and the development of inquiry attitudes that encourage the construction of new meanings in the science learning process. (Porlán, 2018).

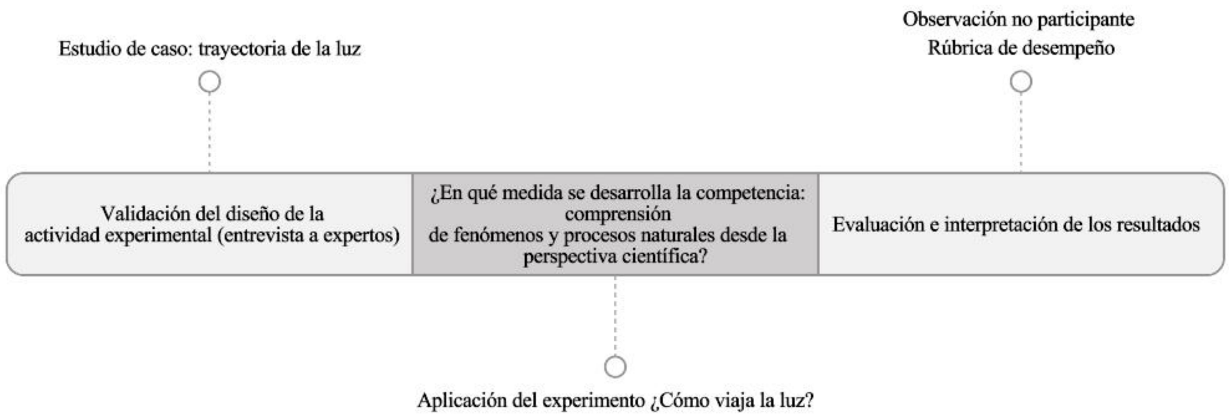
Through experimental activity, it is possible to acquire skills and develop critical thinking (Neira, 2021). For the purposes of this research, an experimental prototype was developed related to one of the learnings proposed by the Mexican curriculum, referring to light and its interactions. In this, from an approach aimed at building skills for inquiry, questioning and argumentation, it is intended that students understand that the path of light is in a straight line. (SEP, 2017).

Materials and method

The methodology is oriented from the interpretive paradigm; seeks to deepen the knowledge and understanding of the development of scientific skills (Poy and Ávalos, 2016). The foregoing under a qualitative approach that attends to a case study to obtain a deep and contextualized interpretation of the phenomenon of interest (Bhattacherjee, 2012). In this investigation the light path was chosen. The objective was to analyze the level of achievement of the competence to understand natural phenomena and processes from a scientific perspective, through the application of an experimental activity related to the path of light as a case study.

The research was carried out in five phases (see figure 1): case selection, question, data location, analysis and interpretation, and results (Poy and Ávalos, 2016). Immersed in the process is the design of the experimental activity referring to the phenomenon of the trajectory of light, a prototype that underwent a design validation moment.

Figure 1. Phases of the research process



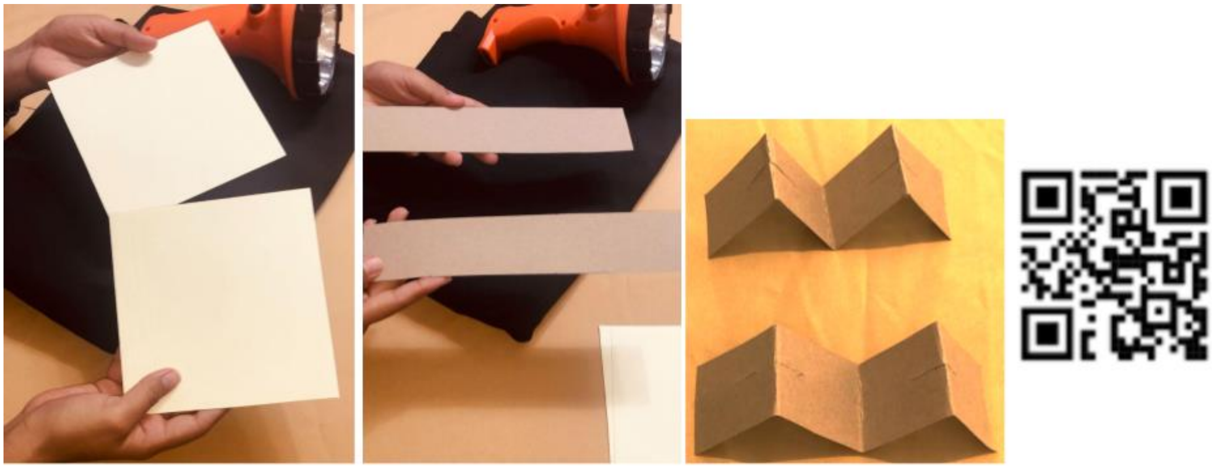
Source: self made

The study subjects were 59 students from 8 to 10 years old who attend third and fourth grade of primary education in the state of San Luis Potosí, Mexico. The participants were selected through a theoretical (non-random) sample (Bhattacherjee, 2012) from three public schools. In the development of this research, digital tools were used for data collection (Hine, 2011), among which are a virtual Classroom, WhatsApp groups, Google forms and a YouTube tutorial linked to a QR code.

Experiment design

The experimental activity "How does light travel?" (VanCleave, 2014) implemented in this research was related to the case study phenomenon referring to the path of light. However, to support the operational part of the experiment and guide the participants in the development of the procedure only, a tutorial linked to a QR code was created, which allowed instant access (see figure 2). The materials consisted of a flashlight, two 15 cm × 15 cm pieces of cardboard, two 25 cm × 5 cm cardboard strips, a ruler, and black cloth.

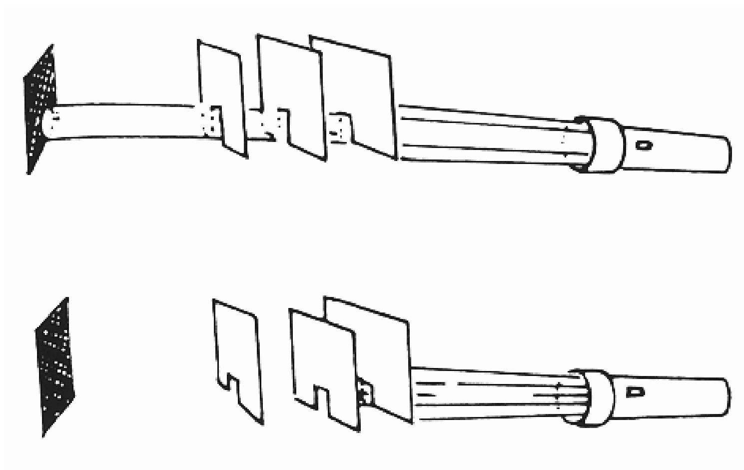
Figure 2. Materials and QR for the experiment tutorial



Source: self made

During the procedure of the experimental activity, the participants built supports with cardboard strips, located the center in each cardboard and made a hole; This allowed us to observe the path of the light, since when the flashlight was turned on, the light rays were observed to go through the holes in the cardboard in a straight direction, as shown in figure 3.

Figure 3. Experimental activity “How does light travel?”



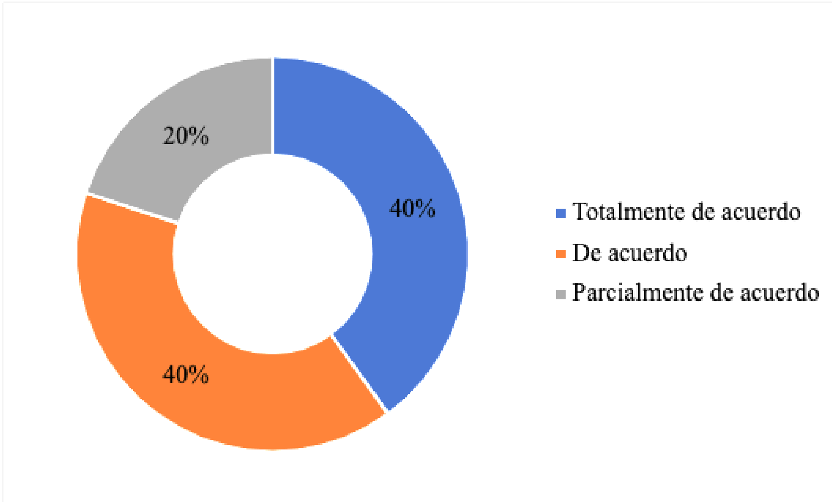
Source: VanCleave (2014, p. 193)

The purpose of selecting this experiment meets the provisions of the Mexican curriculum, which initiates primary school students in the study of optical phenomena so that they recognize the characteristics of light from its interaction with objects (SEP, 2011). Another of the criteria was related to the use of materials, since they were available to the participants who developed the experimental activity. In this sense, Egorov and Zuykov (2017) refer that it is possible to teach physics in childhood with affordable prototypes. In addition, they emphasize going from the simple to the complex and relying on free inquiry.

For the validation of the design of the experimental activity, an interview was applied to five expert volunteers in the area of pedagogy, technology, physics and educational physics, in order to know their perspective about the experiment and validate its development. The questionnaire was distributed electronically and consisted of six questions: 1) "What is your perspective regarding the materials suggested by the experimental prototype?", 2) "What is your perspective regarding the procedure of the experiment?", 3) “Do you consider that the experimental prototype favors the understanding of the path of light in third and fourth grade children (8-10 years old)?”, 4) “Do you consider that the experimental prototype contributes to the development of the competence to understand natural phenomena and processes from a scientific perspective?”, 5) “Do you consider that the prototype of the experiment allows the third and fourth grade student of the primary level to develop thinking skills, as well as scientific language? ” and 6) "Do you consider it necessary to make adjustments to the prototype of the experiment to achieve an understanding of the path of light in third and fourth grade students?"

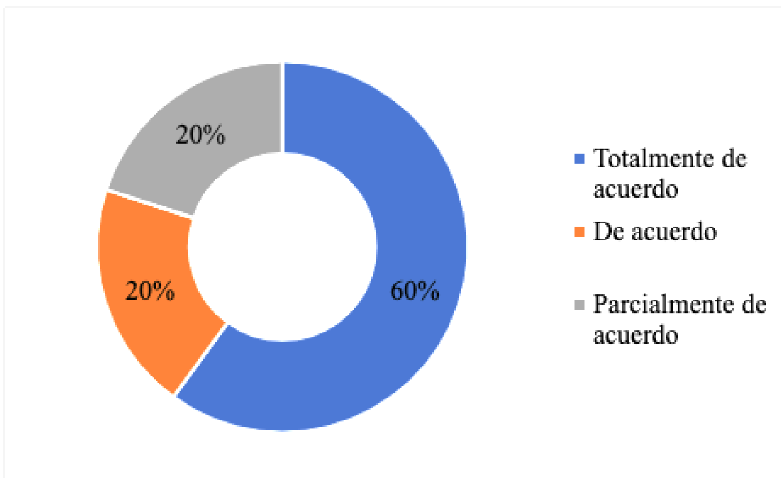
The graph in Figure 4 retrieves the results of the applied instrument. In this it is observed that the experts, to a greater extent, agree with the relationship between the design of the experimental activity and the optical phenomenon. Regarding figure 5, 60% of the interviewees indicate that the experiment "How does light travel?" It allows the development of the competence to understand natural phenomena and processes from a scientific perspective. Thus, when the experts agreed on the design of the experiment, the application phase was advanced.

Figure 4. Validation of the experimental design and its relationship with the light path



Source: self made

Figure 5. Validation of the experimental design and its usefulness to develop competencies



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To assess the level of development of scientific competence, a performance rubric was designed. In this, the knowledge, attitudes and skills of the participants were assessed during the experimental activity. The criteria are concentrated in table 1. These meet the characteristics: relevance, hierarchy, independent and concrete, fundamental elements in the design of criteria to evaluate competencies. (Ruiz, 2015).

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Table 1. Evaluation criteria for scientific competence

Conocimientos (C1)	Reconoce que una de las características de la luz es su propagación en línea recta.
Habilidades (H1)	Formula preguntas y plantea hipótesis respecto a la trayectoria de la luz.
(H2)	Comunica los resultados de observaciones y la actividad experimental utilizando diversos recursos; por ejemplo: esquemas, dibujos y otras formas simbólicas.
(H3)	Elabora inferencias, deducciones, predicciones y conclusiones respecto a la trayectoria de la luz.
Actitudes (A1)	Expresa curiosidad acerca de los fenómenos y procesos naturales en una variedad de contextos y comparte e intercambia ideas al respecto.
(A2)	Manifiesta honestidad al manejar y comunicar información respecto a fenómenos y procesos naturales estudiantes.

Source: Own elaboration based on SEP (2011)

Results

In this phase of the case study, the results obtained in two moments were identified. First, after data collection, they were coded (Bhattacherjee, 2012) and categories of analysis were identified based on the responses obtained by the participants to the questions posed at the end of the experimental activity: "What did you learn by performing the experiment? " and "How did you feel?" Second, a performance rubric was used as an evaluation instrument to recognize the level of achievement of the understanding of natural phenomena and processes from a scientific perspective.

The answers to the question "What did you learn by doing the experiment?" they were concentrated and categorized from higher to lower frequency. These are illustrated with textual words that some of the participants used to explain what was observed regarding the phenomenon of the path of light during the experimental activity.

a) Category 1: Students who answered "How light travels" without formulating an explanation of what was observed (36/59).

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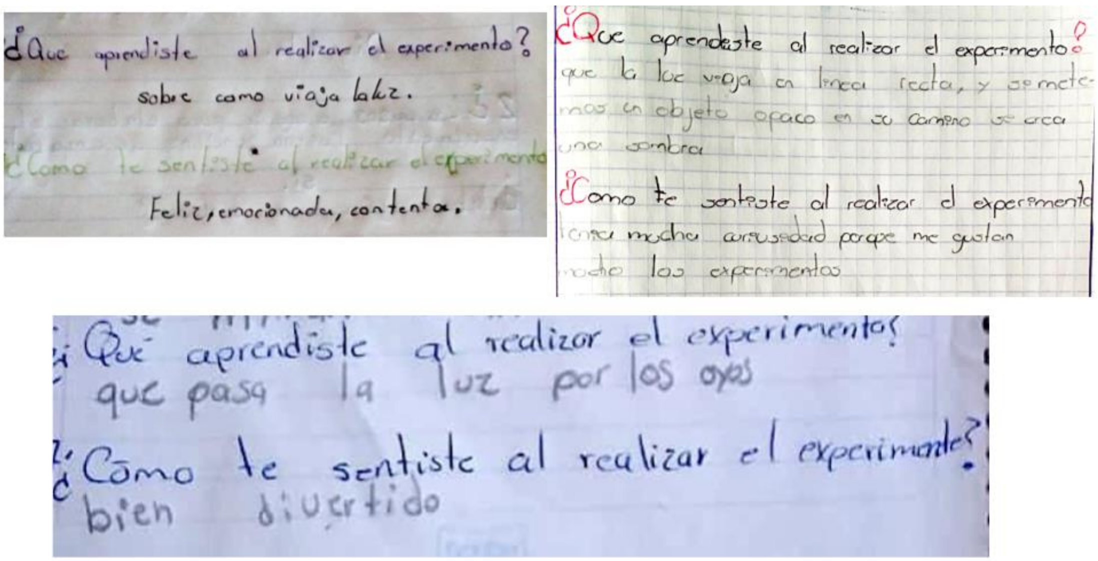
b) Category 2: Students who identified that light rays go through the holes in the cardboard (17/59).

c) Category 3. Students who related what they observed with the sun's rays (3/59).

d) Category 4. Students who identified the path of light in a straight line (3/59).

Figure 6. Participant responses



Source: self made

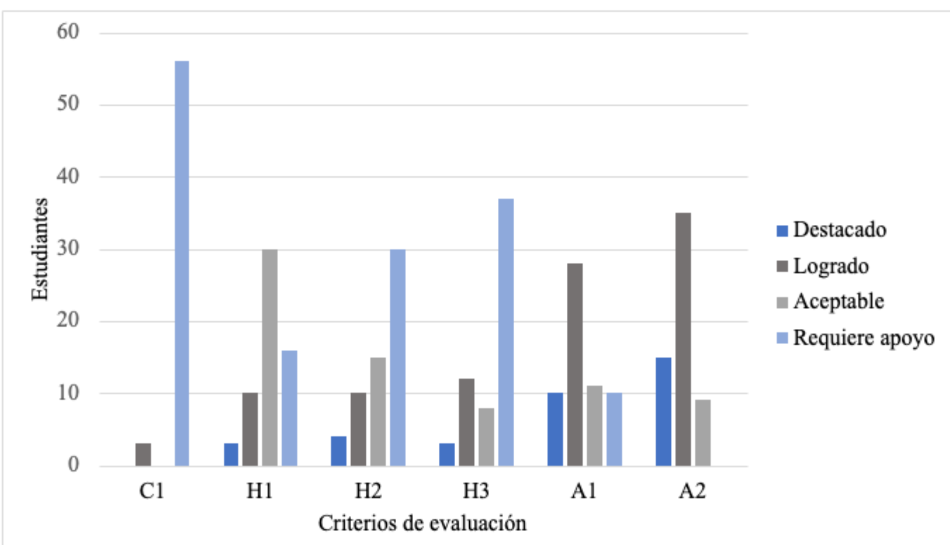
The results show that most of the participants used the title of the experimental activity "How does light travel?" to describe what was learned in the development of the prototype, without delving into the optical phenomenon. This leads to a lack of certainty to take for granted that they managed to understand that the path of light is in a straight line. On the other hand, some used their observations of light rays passing through the holes in the cardboard to formulate hypotheses. In this sense, they considered their experiences to build their first explanations of what happened in their environment (García and Moreno, 2020), but without using scientific language. In this case, the experimental activity represented a resource to identify various perspectives that need to continue to be built (Amelines and Romero, 2017).

Regarding the question "How did you feel when performing the experiment?", most of the participants gave the qualifiers "excited", "curious" and "good". This reflects that, during the age of 8 to 10 years, children like to carry out experiments in science class (Arce, 2002). Hence the importance of promoting teaching that responds to the interests of students and promotes the development of scientific skills.

The results of the performance rubric applied to each participant were concentrated in a graph that reflects the level of competence, which depends, according to Pedrinaci (2012), on "the ability to integrate their knowledge, skills and attitudes in the interaction with the physical phenomenon" (p. 202). In figure 7, it is observed that C1 obtained a level of "Requires support", because it was difficult to describe that the light path is in a straight line. Regarding H1, the "Acceptable" level predominates, this means that on occasions questions were elaborated and hypotheses were raised but with little relation to the subject. However, criteria A1 and A2 reflect that most of the participants reached an "Achieved" level with respect to the field of attitudes. In this sense, they showed interest in the optical phenomenon, shared and exchanged some ideas about it.

However, what represented a lower level of performance in the achievement of the competition corresponds to the fact of recognizing that the trajectory of light is in a straight line, since in their records elaborated to explain what was observed, the children made use of previous experiences (Harlen and Qualter, 2004); but they have been few regarding the study of optical phenomena, therefore, they use everyday language. In this sense, it will be important to continue implementing experimental activities that contribute to promoting student interaction with the learning of optical phenomena from an early age and scientific literacy. (Carreras, Yuste y Sánchez, 2007).

Figure 7. Performance Rubric Results



Source: self made

On the other hand, the criterion with the highest performance corresponds to the attitudinal field, since a level of "Achieved" was reached in more than half of the students. This means that they showed interest in the experimental activity and expressed pleasure during the development of the experiment. In this sense, Dapía, Vidal and Escudero (2019) point out that in the first grades of primary education, children show a positive attitude towards the study of science. This implies the importance of the teacher's role in providing opportunities for the development of attitudes associated with the study of science. (Harlen y Qualter, 2004).

Discussion

One of the observations made in the process of validating the design of the experimental activity highlighted the importance of linking situations of daily life to promote understanding of the path of light and contribute to the development of scientific skills. Likewise, it is necessary to design a didactic sequence that contains moments for the recovery of previous experiences regarding the observed phenomenon, the demonstration and reflection of the experiment, in order to increase interactions and achieve scientific thinking from childhood. In addition, it will be important that the materials and the procedure described meet the characteristics of the educational context, that is, the reach and knowledge of the students.

The development of this research allowed to fulfill the objective, since, through the case study, the level of achievement of the competence was analyzed: understanding of natural phenomena and processes from the scientific perspective, through the application of an experimental activity related with the path of light. It was recognized that the students began to possess knowledge and show curiosity regarding the observed phenomenon, however, it is still necessary to delve into the meaning of scientific knowledge (Castro and Ramírez, 2013), and go from demonstration to theorization (Amelines and Romero , 2017). The limitations were found in the lack of collaborative interaction between the students, because this experiment was carried out individually, this represents an aspect to consider for future research.

Conclusions

The teaching of optical phenomena at an early age implies a challenge for teachers because one of the main obstacles is related to the lack of mastery of the content and updating on the didactics of science at the primary level. In this sense, it is necessary to continue conducting research to recognize alternatives that contribute to the training process and promote interest in the study of science from an early age. To achieve this, inquiry and experimental activity represent an important tool.

Finally, new approaches have emerged as a result of the results obtained, it will be important to investigate the effects of using the experimental activity immersed in the development of a didactic sequence and recognize the relevance of accustoming students, from the first educational levels, to the formulation of explanations about the optical phenomena that occur in their environment from a scientific perspective.

Future lines of research

As a result of the challenges that have recently been triggered in the educational field, it is necessary to deepen the analysis of didactic proposals that are innovative for the study of science and contribute to the development of critical thinking from an early age. It will be important to consider the use of technology as a means of learning, recover the importance of social interaction and promote scientific thinking that makes it possible to solve problems of daily life.

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Rol de Contribución	Autor (es)
Conceptualización	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Metodología	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Software	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Validación	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Análisis Formal	Claudia Carolina García Gaitán
Investigación	Claudia Carolina García Gaitán- principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Recursos	Claudia Carolina García Gaitán- principal Mario Humberto Ramírez Díaz- igual Carlos Adrián Arriaga Santos- igual
Curación de datos	Claudia Carolina García Gaitán
Escritura - Preparación del borrador original	Claudia Carolina García Gaitán
Escritura - Revisión y edición	Claudia Carolina García Gaitán - Principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Visualización	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Supervisión	Claudia Carolina García Gaitán Principal Mario Humberto Ramírez Díaz- Igual Carlos Adrián Arriaga Santos- Igual
Administración de Proyectos	Claudia Carolina García Gaitán – Principal Mario Humberto Ramírez Díaz- que apoya Carlos Adrián Arriaga Santos- que apoya
Adquisición de fondos	Claudia Carolina García Gaitán – principal Mario Humberto Ramírez Díaz- igual

	Carlos Adrián Arriaga Santos- igual