The Study Of Art: A Motivation To Learn Physics

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Abstract

Introduction: Physics, particularly modern physics, challenged the students in different dimensions, from the abstract concepts themselves to the experimental difficulties in demonstrating those concepts. Linking physics and art could enhance understanding for both areas. This paper analyzed the methodology of implementation and presents several reflections with a view to other contexts and educational levels.

Methods: A quasi-experimental study using Project-Based Learning (PBL) was conducted with a high school group, challenging them to create original artwork about light for a science communication contest. The eight-session intervention included labs on the behavior of light, spectroscopy, and the use of UV light. Conceptual learning was assessed using a pretest/posttest and analyzed using Hake's factor.

Results: This research describes the results obtained from working with a group of high school students on the applications of physics in the analysis of works of art. The experimental group that used the interdisciplinary methodology of art and physics (ABP) had a significantly greater conceptual gain than the control group. In the final evaluation (post-test), the average score of the experimental group was 7.3, considerably higher than the 5.8 of the control group. The analysis showed that the experimental group increased their scores by 40%, compared to 15% for the control group. Interviews revealed that students perceived a clear connection between physics and art as complementary ways of understanding the world. In addition, the project was a success with two students from the group winning awards in the magazine's national competition.

Discussion: It is noteworthy that contextualized teaching, using art as a motivating factor, contributes to promoting meaningful learning. This approach fosters the development of essential soft skills, such as critical thinking, creativity, and the ability to integrate knowledge across multiple disciplines. The success of the proposal was attributed to effective interdisciplinary collaboration between art and physics teachers. Students validated the connection, perceiving physics and art as complementary (methodical and emotional) ways of understanding the world. Finally, the need for future research on the implementation and long-term impact of these interdisciplinary approaches in other educational contexts is emphasized.

Keywords: Physics Education, Art, Project-Based Learning, UV light

INTRODUCTION

For a long time, there have been persistent myths surrounding learning physics, which is often regarded as one of the most challenging subjects due to various reasons, such as the necessity of applying mathematics and the abstraction of some of its fundamental concepts, which is commonly used to justify significant school lag and even school dropouts. Then, physics teachers must seek teaching methods that motivate students and promote learning. There has been significant progress in the study of physics and its applications in various fields, ranging from basic research to biology, medicine, economics, art, and technological development. Advancement in Physics has not only deepened our understanding of fundamental natural phenomena but has also led to the development of a wide array of

techniques that have practical implications far beyond traditional scientific boundaries. One such field where physics has found intriguing applications is art history.
Since Art, unlike science, can be appreciated by almost everyone, it is logical to wonder: Why not use Art as a tool for teaching science, specifically physics? If a teacher connects Physics with a topic that is widely appreciated—such as Art—then some new possibilities could emerge. As we see, Physics not only helps people to understand and describe artistic expressions, but it can also be a powerful tool for creating Art itself, transforming the way students perceive both disciplines and the inner correlations between them.
Over the past few decades, techniques derived from applied Physics have become invaluable tools in the service of art history [1, 2]. These techniques, which range from radiocarbon dating archaeological artifacts to the study of valuable objects through ionizing radiation, have revolutionized the way we study and preserve cultural heritage. Among the most fascinating applications of physics in this field is the analysis of works of art through non-invasive methods. As we can see, spectroscopic techniques enable researchers to gain insights into the material composition of art, revealing hidden details such as the origin, authenticity, and the methods used during the creation stage.
For some people, it may seem unconventional at the intersection of science and art, mainly because these disciplines have different objectives, methods, and audiences. However, contemporary educational approaches suggest that, when integrated effectively, science and artistic education can complement and enrich each other [3].
Typically, physics and chemistry are essential disciplines for the study of Historical-Artistic Heritage [4]. These sciences enable us to verify the authenticity of artworks, determine the origins of materials, and understand the techniques used in the creation of most historical objects. These disciplines play a crucial role in the restoration and conservation processes, helping to preserve our cultural heritage for future generations.
One excellent opportunity for contextualized learning is presented by connecting physics and art in science classes. The primary goal of interdisciplinary education is to teach students how to connect content from different fields to solve problems, thereby helping them integrate knowledge and develop skills beyond the classroom [5]. In this sense, one of the biggest challenges in science education is making abstract concepts accessible and engaging for students. Traditional methods are not effective for all students, particularly when teaching topics such as the electromagnetic spectrum and light behavior [6, 7].

1.1 Problem definition

The *Bachillerato Nacional* is a recent initiative of the Mexican government, scheduled for implementation in the 2025–2026 school year, which seeks to unify the diversity of offerings in high school education. Its goals include establishing a common curricular framework, strengthening both comprehensive and technical training, and expanding coverage by reducing the fragmentation among subsystems. Furthermore, the reform envisions providing graduates with dual certification: one as a general high school diploma and another as a technical qualification, with an emphasis on scientific, technical, and humanistic knowledge.
Within this broader national context, the Universidad Nacional Autónoma de México (UNAM) offers two distinct educational models at the high school level. Almost every 14–15-year-old student is required to choose among the available options, and schools across the country may pay a fee to adopt the official UNAM curriculum and access its study materials. However, to be part of the Integrated System (SI), these schools must fulfill a large number of requirements.
In the specific educational model of High School Education (SI), all first-year students take a mandatory course of Physics called *Physics III,* which is perceived as the most challenging course to pass and understand due to the complexity of abstract concepts involved.

Typically, students have poor or no memory of their previous Physics courses, and it has been 1 or 2 years since they last studied those topics.
For most physicists, physics applications and correlations in the real world are easy to see and understand in everyday life. However, that connection is not always easy to see for other teachers outside the field, and even less so for students.
From the very beginning, humankind has felt the need to share information; in this way, images have played a crucial role in fulfilling this purpose. As civilizations evolved, drawings and pictures became increasingly complex, initially illustrating historical and philosophical ideas, and later capturing aspects of the natural world with greater accuracy. Hence, drawings developed into a powerful tool for scientific investigation.
Then drawing involves more than simply capturing what you see; it includes the conception of an idea, an archetype, and finally, a prototype. These three aspects are fundamental and highlight why a photographic image cannot replace drawing. While photography can function as a complementary tool for drawing, it fails to capture the depth and detail achieved through the human hand [8].
As a teacher, occasionally it is a challenge to find a balance between art and science. The given nature of each discipline could sometimes be incompatible. For most common perceptions, physics tends to be logical, characterized by convergent thinking, which involves a linear progression of problem-solving and a unique final solution. In contrast, the arts tend to include activities that involve creativity and divergent thinking, engaging students to share their own personal experiences and perspectives. Even though these disciplines are treated as distinct today, their historical paths are fundamentally intertwined. It is undeniable that they both aim to show and interpret the natural and real world as they perceive it [9].

1.2 Objective

Nowadays, most people enjoy and appreciate art. Taking into account this fact, we have as an aim to discover how a physics teacher can use the analysis and creation of art as a motivator for learning science.

2 THEORETICAL FRAMEWORK

Today's students are entirely different from those of some years ago. Modern students are less interested in learning science in a conventional way and want new experiences that interest and motivate them. This fact has led physics teachers to feel compelled to transition from the traditional master class to a new educational approach that emphasizes student engagement and independence.
As it is essential nowadays to acquire competencies rather than a fixed body of knowledge, physics teachers are using various didactic methods to enhance students' skills and knowledge in physics. Among all these methods, project-based learning (PBL) [10, 11, 12] has demonstrated its value in helping students acquire knowledge and understanding of physics, while also developing their analytical and reflective thinking skills. In PBL, students work collaboratively with others and learn to learn from one another.
It is essential to note that project-based learning can engage students in activities and topics that are interesting to them, and it is an effective way to promote interdisciplinary learning. When projects situate learning in context, knowledge acquires meaning, and students feel motivated.(cita) [13, 14].
The development of projects increases the autonomy of students, who become more responsible and improve their achievement as they need to practice higher levels of thinking through the direct application of knowledge in making interpretations, conclusions, and critical judgments. Additionally, projects enable students to make interdisciplinary connections and develop research and social skills. Additionally, one of

the significant advantages of developing projects is that they can be used in courses where students have diverse learning preferences.
On the other hand, projects encourage students to use their creativity while working cooperatively with their peers. They learn to be empathetic towards others, to listen and communicate effectively, to make informed decisions within a team, and to solve problems through collaboration with their peers. These skills will be highly beneficial in their future studies and professional development.
Projects also provide teachers a way to cross disciplinary boundaries and create learning goals that combine different subjects. For example, in this work, there is a combination of art and physics concepts.
If we combine the development of projects with the situated learning theory, we can motivate students to learn physics even more. The concept of situated learning is based on the idea that knowledge is constructed in specific contexts and in interaction with the environment. In this line of thinking, combining art and physics could be a good idea to improve the understanding of the basic concepts of physics.

3 PROPOSAL AND METHODOLOGY

The study was conducted within the SI educational model at a high school in Mexico City, an institution that provides pedagogical education for students preparing to pursue higher education. The student body is characterized by a broad cultural background, which therefore enriches the academic environment and shapes classroom interactions. All students have access to personal computers, smartphones, and the internet. Additionally, the school community, including students, teachers, and administrative staff, utilizes an internal communication platform that facilitates the distribution of assignments, exams, reminders, and other relevant information.
The proposal required six theoretical sessions and two experimental sessions, totaling eight hours. We work with two different groups, and the assignment of the students in each group was made randomly by the school's administrative staff, without any specific criteria. Within the experimental group, students were divided into teams of four each, allowing them to work collaboratively during the experimental sessions. All teams and students stayed together till the end of the final exam to ensure the consistent and complete execution of all the activities.
For the experimental group, we have three different phases: the pretest evaluation, the implementation of the proposed activities, and the final post-test evaluation. The proposed activities are described in detail as follows:
In the first session, we administered the pretest to all students and provided them with the instructions. One student from each team of four was selected for an individual interview to explore initial perceptions about light, the electromagnetic spectrum, and their perceptions about physics, art, and the connections between them. The students completed the pretest individually, while the selected students participated in the interviews.
In the second session, we introduced the PBL methodology and explained the objectives of the activities, encouraging students to participate in every proposed dynamic. We also presented the science communication activity, which was a nationwide call for submissions from students in Mexico to design the cover for the December edition of the science magazine titled *¿Cómo vés?* Students were challenged to create original artwork that explored topics in natural or social sciences, technology, history, or the philosophy of science under the theme of light. A key rule was that all drawings had to be completely original, so using AI-generated images was forbidden.

This magazine is a monthly journal of the General Directorate for Science Communication, which has been published uninterruptedly since 1998. It is the only science communication magazine in Mexico specifically aimed at high school and early undergraduate students. The contest aims to showcase creative and original handmade artwork, developed under the guidance of physics and art teachers from diverse contexts across the country. Each participant must send their work by email to the organizing committee using their institutional email address and attach a copy of their student ID.

All submissions were judged by a professional panel that included designers, science communicators, and members of the magazine's editorial team. The winning design was selected for publication on the cover, and the winning student received a monetary prize. Additional designs were chosen for publication within the magazine's interior, also accompanied by a monetary prize. Nevertheless, during this session, the teacher provided examples of how light has been represented in artworks throughout history, showing different examples. During this discussion, the students shared their initial ideas about the relationship between light and art.

During the third session, we explained the main concepts of light behavior, including reflection, refraction, and dispersion, as well as some concepts around the electromagnetic spectrum, using visual resources and PhET simulations. We guided short prediction exercises. The students solved small conceptual exercises by themselves.

In the fourth session, which took place in the laboratory, the teacher organized the students into teams of four and provided them with materials for an experiment on the reflection, refraction, and dispersion of light. The teacher monitored teamwork and guided the discussion of results. The students conducted the experiments, recorded their observations, and took photographs to include in the final laboratory report.

During the fifth session, the teacher explained the principles of spectroscopy and some of its applications in both physics and art. The teacher worked with real case studies using Remedios Varo's work, demonstrating how spectroscopy has been applied to artwork analysis and conservation. Here the students, in groups of four, discussed how spectroscopy can reveal information about pigments and materials in artworks.

In the sixth session, we introduced the use of ultraviolet light in the laboratory to analyze Mexican banknotes of different denominations. The teacher explained how UV light reveals hidden details not visible under normal illumination and supervised the activity. The students observed the banknotes under UV light, discussed how this technique relates to physics, security, and authentication, and wrote conclusions about the activity to add to their final laboratory report.

In the seventh session, the teacher led a group discussion and asked guiding questions about the role of physics in understanding both art and everyday applications. The students shared their team conclusions and discussed the connection between what they saw and what they had discussed on the previous days.

In the eighth session, we administered the post-test and interviewed the same student from each group who had been selected in the first session. The students completed the post-test individually. On this day, they presented and sent their drawings to the organization's magazine committee. The objective of the organizing committee was to foster the engagement of young students in scientific communication using visual media.

4 RESULTS

The case of study focused on the teaching and learning process of light behavior and the electromagnetic spectrum through the lens of spectroscopy techniques in art analysis. The intervention involved two groups of 30 high school students each, aged between 15 and 16 years old.

The instrument used to evaluate the student's conceptual gain consisted of 10 questions with five possible responses; each question had only one correct answer and was shared through the school's internal communication platform. This platform offers several advantages over others, including the random presentation of questions to each student, a time limit for completing the test, and a link to their student account profile.

The results of the intervention were analyzed by comparing the performance of the experimental and control groups in the pretest and post-test. Figure 1 shows the distribution of total points obtained per question and the number of correct answers per group, in both groups at the pretest evaluation. Figure 2 shows the students' scores obtained in the pretest examination for both groups. The experimental group displayed a higher concentration of students achieving grades 2 and 5, whereas the control group showed higher frequencies at grades 3 and 4. The average experimental group score is 3.6, and the average control group score is 3.8. It is important to emphasize the higher initial score for the control group.

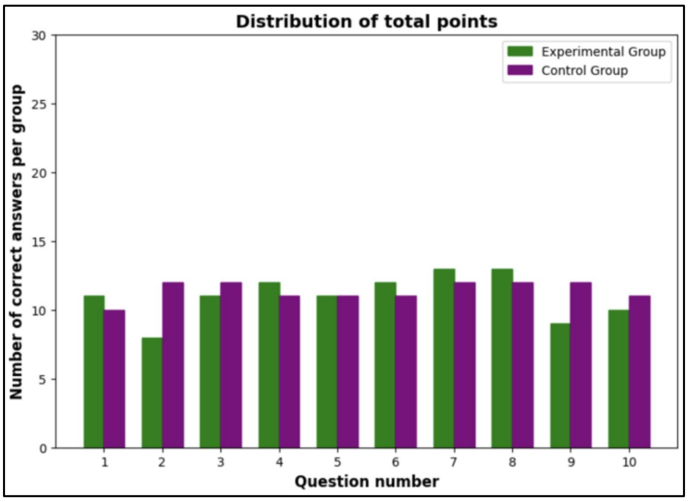

Figure 1. Distribution of total points obtained per question and the number of correct answers per group, in both groups at the pretest evaluation.

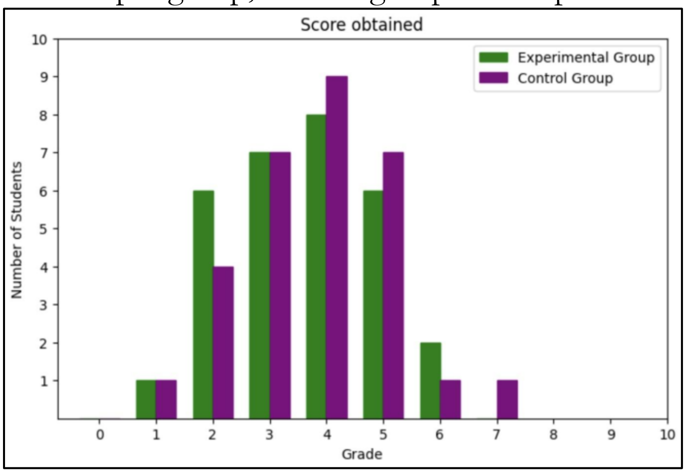

Figure 2. Students' scores obtained in the pretest examination at the pretest evaluation.

In contrast, Figure 3 shows the distribution of total points obtained per question and the number of correct answers per group, in both groups at the post-test evaluation. Figure 4 shows the students' scores obtained in the post-test examination for both groups. The distribution revealed that the control group had a more balanced performance between grades 3 and 8. In contrast, the experimental group showed higher frequencies between 6 and 8, while the control group exhibited a broader distribution with a peak at grade 8. The average score of the experimental group is 7.3, while that of the control group is 5.8. This indicates that both groups improved their average scores, regardless of the learning methodology applied.

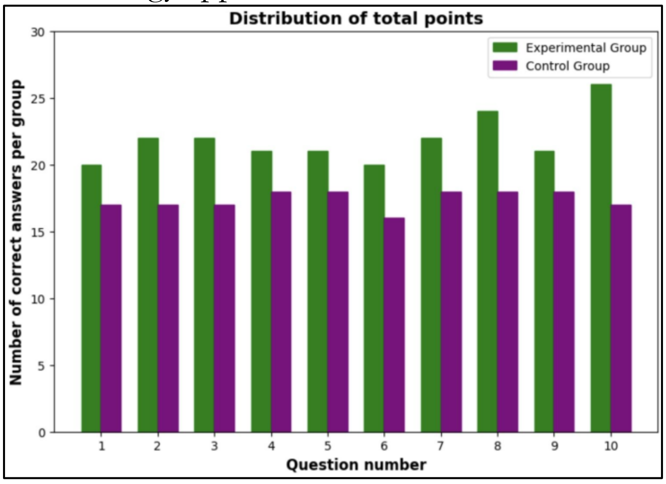

Figure 3. Distribution of total points obtained per question and the number of correct answers per group, in both groups at the post-test evaluation.

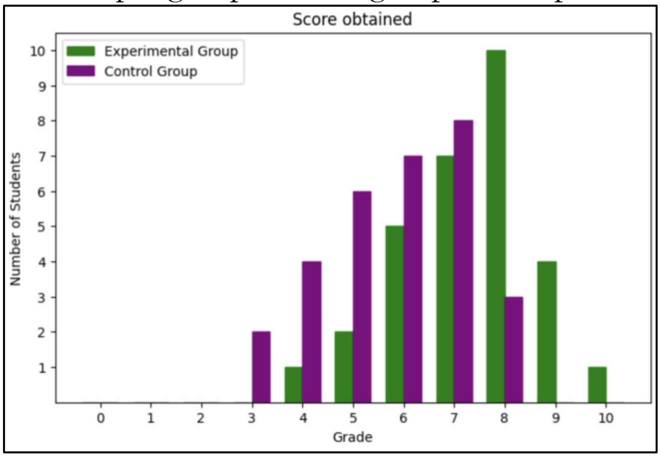

Figure 4. Students' scores obtained in the post-test examination for both groups at the post-test evaluation.

In terms of academic performance, the statistical analysis of the pretest and post-test results using the Hake factor was significantly higher for the experimental group, indicating an improvement in the experimental group compared to the control group. The experimental group demonstrated a 40% increase in test scores from the pretest to the posttest, compared to a 15% increase in the control group. Nevertheless, both groups showed improvements in their final test scores, suggesting that traditional methods also yield positive effects.

We conducted several interviews and evaluations to gain insight into the students' perspectives on the proposal. Here is a fragment of one of them:

… physics is a way to explain the process by which we create something. This is connected to art because it is beautiful to realize how the things you do can lead to something that you would have never imagined. Like in a painting, you add brushstrokes and little by little you arrive at a complete picture; in physics, little by little you add different pieces of knowledge that help you reach a result. It is connected to art, because when someone goes deeper into physics, they can picture and create paths, and even if you get lost, in the end, you will find another way to understand the same problem.

In this way, students' responses show that they see physics outside the classroom context and also understand that different areas of knowledge can work together to get better.

From the interviews, we gathered different students' perspectives on the connections between physics, art, and light behavior. Some of the students had a common experience

with the magazine contest; they took it very seriously. After we conducted interviews with the winners to gain insight into the students' perspectives on the whole learning experience:
I believe that both physics and art are ways to understand your surroundings, and even your own mind. They are both activities carried out by humans, and so they have our footprint, they are limited to our human perspective, which is something normally only attributed to art, however physics lies under this category as well, they differ, physics is more methodical, art is more emotional, however they serve the same purpose, physics and art are extremely different paths to one objective, and two halves of the same whole, human; understanding of the world.
Another winner perception:
… physics and art are two sides of the same coin; the way physics and art relate is astonishing. Both have the same way of learning about someone or something, the meaning of physics being *the study of our surroundings* is amazing, since you can learn about how the simplest things, like a pen on a desk, still have physical properties! Meanwhile, art is the way of understanding the human, we express through art in the most sincere and crude ways, we let every emotion out when we are doing OR enjoying art.
All in all, the interviews revealed that students perceive a clear connection between physics and art, recognizing both as complementary ways to understand the world around them. While physics provides a methodical approach, art offers an emotional and human-centered perspective. Together, these approaches empower students to engage with their surroundings and themselves. The students’ reflections suggest that integrating physics and art into learning experiences could offer valuable interdisciplinary opportunities in education.

5 FINAL REFLECTIONS AND CONCLUSIONS

As discussed above, teaching in context, with art as a potential source of motivation, may contribute to fostering meaningful learning by providing students with a sense of purpose and relevance in their studies. Within this framework, the different activities described appear to support the development of students’ self-esteem, promote the recognition of others’ work, and encourage a range of transferable skills, including critical thinking, creativity, problem-solving, and the ability to integrate knowledge across multiple disciplines. These competences—often referred to as soft skills—are considered essential in everyday life, regardless of whether the student will become a physicist or not.
One of the pedagogical tendencies suggested by the educational model we work with is the multidisciplinary learning approach. In this context, teachers saw different benefits in asking for the same learning product for both classes. A big challenge in the proposal was to participate in the cover magazine draw. All the success came from the interdisciplinary collaboration between the art and physics teachers.
Several months after the contest, the magazine's communication committee revealed the winners on its official website. We were proud to announce that two of the three top prizes were awarded to our students. During interviews with the winners, a key observation was their high level of self-confidence regarding their creative abilities and their capacity to deal with new challenges.
From a teacher's perspective, some of the most interesting students of all time are the artists themselves, who understand that they will become better artists if they understand the physics concepts involved in their own artwork. From that particular point of view, they get internal motivation to be curious about what they can perceive from their surroundings.

A natural question came up after reading this proposal: Is it possible to implement these activities in a different environment, one shaped by its own unique characteristics? Considering that the new student population may differ significantly from the one previously described, this becomes an important issue to address. From a research perspective, future studies could investigate how interdisciplinary approaches can be effectively incorporated into broader curricula. For instance, this proposal could be implemented in a state school setting, potentially yielding comparable results while adapting to a different perspective and cultural context.

This study also invites researchers to examine the long-term impact of interdisciplinary and contextualized approaches on student learning and engagement. There is an undeniable need to investigate how these approaches can be scaled up and adapted to different educational contexts, and it will certainly require the involvement of several scholars.

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Data availability statement

The data supporting the findings of this study are available from the corresponding author, upon reasonable request.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

B.S., M.V., C.M. designed the study. B.S., M.V. collected data. M.V., C.M. curated and analyzed the dataset. B.S., M.V., C.M. wrote the first version of the manuscript. C.M. supervised the project. All authors arranged funding. All authors read, reviewed and approved the final version of the manuscript.

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