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An interdisciplinary model in physics and chemistry for addiction prevention

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ABSTRACT:
The growing prevalence of smoking and vaping among adolescents requires innovative and contextualized educational intervention models. This study presents an interdisciplinary approach in Physics and Chemistry for addiction prevention at a technical high school in Mexico City. The intervention, developed as a classroom project with 25 students, sought to illustrate the effects of smoking through experimental and reflective activities. In Physics, principles such as Hooke's Law were applied to explain respiratory mechanics and lung damage; in Chemistry, educational materials were designed to analyze the molecular composition and biological effects of vaping. The proposal was enriched by an interview with an expert psychiatrist, whose testimony validated the relevance of the approach and offered a comprehensive view of the problem.Qualitative findings, derived from students' learning products (posters, prototypes) and reflections, demonstrate that hands-on activities fostered a deep understanding of the risks associated with smoking and vaping. Participants recognized that the model raised awareness among their peers, thus contributing to prevention from an educational perspective. We conclude that the integration of experimental sciences is a viable and effective pedagogical strategy for addressing public health problems, promoting critical and situated scientific literacy. This model directly aligns with Sustainable Development Goal 4 (SDG 4) by promoting meaningful learning that transcends disciplinary boundaries and impacts individual and societal well-being.

KEY WORDS:
Interdisciplinary model, Health education, SDG 4, Scientific literacy, Addiction prevention

1. Introduction

Smoking and vaping represent two of the most pressing public health challenges of the 21st century, particularly among adolescents. The World Health Organization [1] reports that approximately 1.3 billion people worldwide use tobacco products, with more than 8 million deaths annually attributable to these substances. Furthermore, global reviews indicate that approximately 8.6% of adolescents have recently tried e-cigarettes [2]. In Mexico, ENCODAT shows that tobacco and legal drug use among young people remains a significant public health problem.

In the research reported by Weitzman [3] it is noted that nicotine is a stimulant that, in high doses, can impair attention and learning [4]; long-term exposure is associated with cognitive impairment, reduced psychomotor speed and decreased cognitive flexibility [5]. The use of any of these substances is associated with higher rates of mental health problems, which may secondarily impact interest, effort and performance [3].

In this order of ideas, this inquiry proposes scientific literacy as an important basis for education and effective participation [6], the plan and program of studies at the Center for Scientific and Technological Studies No. 11 (CECyT 11) of the National Polytechnic Institute (IPN) focuses on the development of skills and critical thinking through problem solving, in addition to promoting research, proposing innovative and creative solutions that favor collaborative work, the appropriation of new knowledge and skills among high school students, the Classroom Project is part of a model that favors collaborative work with an integrative approach to knowledge that strengthens the teaching - learning process and contributes to the comprehensive training of students [7, 8].

Schools play a decisive role in promoting prevention by integrating innovative pedagogical approaches. One promising strategy is interdisciplinary learning, where different areas of knowledge are articulated to address a common problem. This article documents an educational experience that integrated physics and chemistry to prevent addictions at CECyT 11 in Mexico City.

The objective of the research focused on analyzing the contribution of an interdisciplinary Classroom Project in Physics and Chemistry to the prevention of smoking and vaping in high school students at the IPN, highlighting its potential to promote critical scientific literacy and contribute to the fulfillment of Sustainable Development Goal 4, considering the research question: How can the interdisciplinary Classroom Project in Physics and Chemistry contribute to the prevention of smoking and vaping in high school students at the IPN, promoting critical scientific literacy and the fulfillment of SDG 4?

2. Theoretical framework

2.1 Interdisciplinarity in science teaching

Interdisciplinarity has been widely recognized as a pedagogical strategy that integrates knowledge and promotes a broader understanding of complex phenomena [9, 10]. In science teaching, combining physics and chemistry allows students to connect conceptual and experimental frameworks with real-life problems, thus strengthening both understanding and critical reflection.

2.2 Prevention of addictions in schools

Bast [11] proposes a protocol for a school intervention based on multiple components (school curriculum, school policies, community participation), aimed at preventing smoking in adolescents, which supports the idea that interventions implemented in educational contexts have real potential for impact.

In Mexico, in 2023, the classroom strategy was implemented: Addiction Prevention and through the Teachers' Guide, teachers consider different actions, in 2024 the classroom project that takes into account this axis was completed, which students voluntarily took into account due to the observed problem on the way to school and with their family and friends: smoking as one of the main addictions. Benavides et al., [12] point out that the actors involved are not only students, parents and teachers, but it is also a phenomenon that involves the national government and territorial entities to guarantee timely follow-up, in this way the classroom project, the Addiction Prevention strategy and, above all, interdisciplinarity converge through the learning units: Physics and chemistry.

The teachers' guide "Addiction Prevention" indicates that, in Mexico, the average age of initiation of legal and illegal drug use is 13 years old, this fact directly affects the performance of high school students, as well as their comprehensive development and well-being [13], this strategy is based on the implementation of a classroom strategy that informs and contributes to the prevention of drug use among high school students, promoting knowledge and reflection on the characteristics and adverse effects on health ; encouraging the development of self-care and decision-making skills for physical and mental preservation.

2.3 Physics applied to health: Hooke's Law and respiratory mechanics

In physics it is recognized that many phenomena can be understood from simple models, as is the case of Hooke's Law where the debate associated with the manipulation and thinking about objects is involved, so in this topic which is Hooke's Law and which, in the words of Resnick [14] is defined as the relationship between the force applied to an unstretched spring and the amount that the spring stretches when the force is applied, mathematically defined by the equation: $F = -kx$.The application of Hooke's Law to understanding the lung, in contrast to the function of the tobacco-contaminated lung, is that the lung is an elastic structure with an anatomical organization that favors its collapse (like a stretched spring). The elastic properties of the lung are important for respiration; however, they also oppose lung inflation, which depends on the contraction of the inspiratory muscles [15].

The Hooke's Law model helped explain the elasticity of the lungs and how smoking or vaping impairs this function. By simulating mechanical resistance and tissue damage, students gained a tangible understanding of the physiological consequences.

2.4 Chemistry and public health: composition of cigarettes and e-cigarettes

Tobacco is consumed primarily in two forms (cigarettes, cigars, pipes) and smokeless (snuff, chewing tobacco), where smoking is the most common form and is associated with the inhalation of a complex mixture of toxic chemicals and is associated with diseases: cardiovascular, respiratory and various types of cancer [16]. Electronic cigarettes, also known as vaping devices, e- cigs , e- hookahs , mods, vape pens , vaporizers, tank systems or nicotine delivery systems, are portable, battery-operated vaporization devices that simulate the act of smoking by heating a liquid to produce an inhalable aerosol (vapor), known as e-liquid which is a mixture of propylene glycol (PG), glycerin (GLY), flavorings, nicotine in varying concentrations and unusual additives such as tetrahydrocannabinol (THC) or cannabinoid oils (CBD) [17, 18].

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Bonner [19] states that consumers and regulatory agencies need a better understanding of component-dependent toxicity to guide product use and regulatory decisions.

2.5 Scientific Literacy and SDG 4

SDG 4 seeks to ensure inclusive and equitable quality education and promote lifelong learning opportunities. Critical scientific literacy is an essential component of this goal, as it empowers students to make informed decisions about their health and their communities [20]. In this sense, through the classroom project as a project-based methodology that integrates an interdisciplinary approach, physics is considered a key learning unit to consolidate the structure of the subject with the topic of Hooke's Law and chemistry, which takes into account chemical substances that are harmful to health, so that students develop reflections with a tendency towards critical thinking both in learning and in society.

3. Methodology

3.1 Research approach and design

This study was developed using a qualitative, exploratory-descriptive approach, focusing on an in-depth understanding of students' perceptions, experiences, and learning regarding smoking and vaping prevention through an interdisciplinary Classroom Project. According to Dörnyei [21] and Braun and Clarke [22], this approach is ideal for investigating complex and emerging educational phenomena, where the context and the voices of the participants are fundamental.
The design adopted was a case study [23], focused on the experience implemented in the CECyT 11 of the IPN, which allowed documenting and analyzing a pedagogical process in a real learning environment.

3.2 Context and participants

The research was conducted at the Center for Scientific and Technological Studies No. 11 "Wilfrido Massieu" of the National Polytechnic Institute, in Mexico City. A non-probability convenience sample of 25 fourth-semester students was used. This type of sampling is justified by the researchers' direct access to the participating groups and the relevance of analyzing a representative case of educational practice.

3.3 Data collection techniques and instruments

Various techniques were used to obtain information, promoting methodological triangulation:

- Semi-structured interview with a psychiatrist specializing in addictions, with the aim of integrating an expert perspective that would enrich the pedagogical and scientific interpretation of the phenomenon.
- Student products: written reports, experiments (Hooke's Law applied to respiratory mechanics and chemical analysis of tobacco and vaping), and graphic materials generated within the framework of the Classroom Project.
- Focused group discussion: conducted at the end of the project to gather collective perceptions about the learning and relevance of the interdisciplinary activity.

The implementation of the Classroom Project was organized in three phases:

1. Diagnosis: Identification of the problem of smoking and vaping in the school community, through initial dialogue with students and consultation of the *Guide for Teachers: Addiction Prevention* (Government of Mexico, 2023).
2. Interdisciplinary development: experimental and reflective activities that articulated Hooke's Law (Physics) and the chemical composition of cigarettes and vapes (Chemistry).
3. Reflection and closure: Written report preparation and group discussion on critical scientific literacy, addiction prevention, and their relationship to SDG 4.

3.4 Information analysis strategy

The collected material was processed through qualitative thematic analysis [22], which consisted of:

1. Data familiarization: transcription of interviews, systematization of reports, and review of field diaries.
2. Initial coding: identification of relevant fragments associated with the categories of addiction prevention, interdisciplinarity, scientific literacy, and critical thinking.
3. Searching for themes: grouping codes into broader patterns that reflect learnings, tensions, and challenges.
4. Review and refinement of topics: contrast with previous literature and discussion among researchers.
5. Definition and naming of themes: final construction of emerging categories that answered the research question.

This process ensured internal validity through triangulation of sources (students, teachers, experts) and techniques (journals, interviews, products, discussions).

4. Results

The analysis of the data collected from student reports, class discussions, and the interview with the psychiatrist was organized through a thematic analysis [22], which allowed us to identify three main categories: (a) conceptual appropriation of Physics and Chemistry; (b) critical reflection on the risks of smoking and vaping; and (c) student motivation and agency around addiction prevention.

4.1 Interdisciplinary integrative scheme

Figure 1 shows the diagram developed from the Classroom Project work. It integrates three components:

1. **Physics (Hooke's Law and respiratory mechanics):** A spring was used to model lung elasticity and simulate the deterioration caused by tobacco.
2. **Chemistry (harmful substances):** Compounds present in cigarettes and vaping liquids were identified, linking them to toxic effects documented in the scientific literature.
3. **Specialist interview:** The psychiatrist's perspective was incorporated to link clinical experiences with student understanding of the problem.

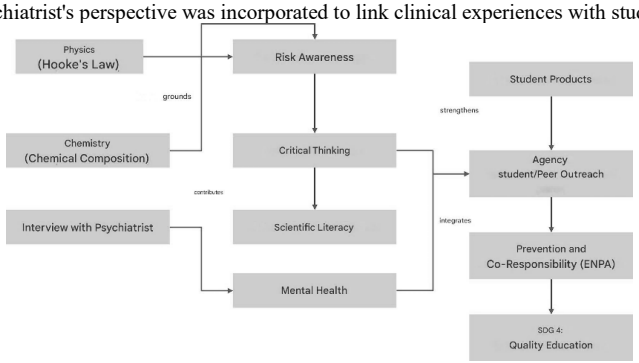

Figure 1. *Diagram of the interdisciplinary model of Physics and Chemistry applied to addiction prevention.*

4.2 Emerging categories from the thematic analysis

Table **1** presents the categories, subcategories and examples of fragments obtained, allowing observe both the conceptual appropriation and the dimension critical and agency student. The nomenclature used for students is Student 1 = St1, Student 2 = St2, and so on.

Table 1. Emerging categories from thematic analysis

Category	Subcategory	Representative fragment
Conceptual appropriation of science	Applied physics	*"When I understood that the lung works like a spring, I saw that smoking causes it to lose that elasticity"* (St. 14).
	Applied chemistry	*"I didn't know vaping had heavy metals; I thought it was just flavored vapor"* (St. 7).

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Critical reflection on risks	Physical health	*"The experiment helped me see how the body is gradually damaged, it is not just a vice"* (St. 19).
	Mental health	*"In the interview the doctor said that it also affects the care, and that worries me because we all have exams"* (St. 22).
Motivation and student agency	Peer prevention	*"I want to explain to my cousins that vaping is also harmful, it is not harmless"* (St. 9).
	Proposal for action	*"We could make a poster for school, showing Hooke's Law with the lung"* (St. 5).

4.3 Analytical synthesis of the interdisciplinary scheme

To go beyond the description and show the integration of the findings, a complementary explanatory table (Table 2) was constructed that organizes the connections of the scheme presented in Figure 1, showing as the conceptual items (Physics, Chemistry, interview) relate to the prevention of addictions and with the Sustainable Development Goal 4 (SDG 4).

Table 2. Relationship between thematic categories and components of the interdisciplinary model

Schema element	Relationship with categories	Empirical evidence
Hooke's Law and Respiratory Mechanics	Conceptual appropriation of science	"When I understood that the lung works like a spring…" (St. 14)
Chemical composition of vaping/tobacco	Conceptual appropriation of science / Critical reflection	"I didn't know vaping has heavy metals…" (St. 7)
Interview with the psychiatrist	Critical reflection on risks (mental health)	"In clinical practice, I have seen that adolescents do not perceive vaping as a real risk…" (Psychiatrist, 2024)
National Strategy for the Prevention of Addictions (ENPA)	Motivation and student agency	"I want to explain to my cousins that vaping is also harmful…" (St. 9)
Health risk awareness	Transversal category: critical reflection	"The experiment helped me see how the body is gradually damaged…" (St. 19)
Critical thinking and scientific literacy	Transversal category	"We could make a poster for school, showing Hooke's Law with the lung" (St. 5)
SDG 4: Quality Education	Global impact of the project	Evidence of articulation between disciplinary learning, addiction prevention and social agency.

4.4 Impact of the interview with the specialist

The psychiatrist's testimony reinforced the validity of the interdisciplinary experience:

"In clinical practice, I've seen that adolescents don't perceive vaping as a real risk; however, the lung damage and impairments in attention are comparable to those of tobacco use" (Interview, 2024).

The students echoed this idea in their reflections, associating the loss of attention with a decline in academic performance.

4.5 Student production

Tangible evidence of learning was manifested in:

- Written reports describing the relationship between lung elasticity and Hooke's Law.
- Informational posters that integrated chemical and physical data with preventive messages.
- Experimental models, for example, simulations with balloons and springs to represent healthy and damaged lungs.

One student commented:

"It was easier to explain to my family what I learned when I showed them the spring and how it represented the lung" (Student 12).

The findings show that the interdisciplinary Classroom Project not only promoted conceptual appropriation of physics and chemistry but also fostered critical scientific literacy by connecting academic knowledge with public health issues and student´s personal experiences. It also generated agency processes by motivating participants to become disseminators of prevention in their immediate contexts.

5. Discussion

The findings show that the interdisciplinary model fostered a critical understanding of the effects of smoking and vaping among students. Through experimental activities in Physics and Chemistry, complemented by interviews with psychiatrists, awareness of the risks of these practices was strengthened and situated learning was promoted. According to Dörnyei [21] and Braun and Clarke [22], the thematic qualitative analysis allowed the students' voices to be recovered as the central axis of the process, while the case study approach [23] made it possible to examine the experience in an in-depth and contextualized manner. In this sense, the Classroom Project was configured as a meaningful educational practice that aligns with the National Strategy for the Prevention of Addictions [24] and with Sustainable Development Goal 4 (SDG 4), by promoting quality education with social impact.

One of the limitations considered important for future research is that this is a single case with a non-probability convenience sample (25 students). This limits external generalizability and the lack of longitudinal assessment to determine the durability of change (for example, whether the "seed" of awareness translates into sustained behavior). It is recommended to implement a quasi-experimental study (comparison groups) with pre-post measurements and 6–12-month follow-up, combining qualitative instruments (interviews, products) with quantitative instruments (knowledge, attitudes, intention to use, self-reported consumption).

6. Conclusions

The interdisciplinary experience developed at the IPN's CECyT 11 demonstrated that integrating physics and chemistry into a classroom project constitutes an effective pedagogical strategy for addressing public health issues such as smoking and vaping. The experimental and reflective activities allowed students not only to understand the scientific foundations of the harm caused by these substances, but also to connect this knowledge to their daily lives.

The inclusion of an interview with a psychiatrist enriched the approach by providing professional support that validated the project's relevance and provided a comprehensive view of the physical and psychological risks of substance use. This element strengthened knowledge acquisition and facilitated the students' development of critical arguments.

The results also show that the Aula Project contributes to addiction prevention through education, in line with the National Strategy for the Prevention of Addictions [24] and Sustainable Development Goal 4 (SDG 4), by promoting inclusive, equitable, and quality education that impacts individual and social well-being.

Finally, it is concluded that the interdisciplinary model presented here represents a viable and replicable way to foster critical and situated scientific literacy, as well as to promote the development of conscious, reflective, and socially responsible students.

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Data Availability

https://drive.google.com/file/d/1SAnOaSrjOXuFsBTPzPMsCxSciCzWIDwx/view?usp=sharing

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