

Using Forensics to teach the Natural Sciences and raise student consciousness about gender-based social issues

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Abstract: The way the Natural Sciences has been conventionally taught in school, i.e., by means of lecture-based methods, has been shown ineffective. For this reason, many alternative methods of teaching and learning have been proposed. This study focuses on the teaching of the Natural Sciences by the employ of ludic investigative activities in the context of forensic science. It proposes an alternative way of teaching the Natural Sciences associated with issues relevant to students and society at large. To this end, a case of femicide was used to teach topics of the Natural Sciences while addressing an important social issue, i.e., gender-based violence. This research, a case study of a qualitative nature, was carried out at Colégio de Aplicação in Macaé (CAp), RJ, Brazil. Its proposed teaching-learning activities were conducted over three consecutive 90-minute classes. The participating students answered pre- and post-intervention questionnaires on the scientific concepts addressed by the activities and the social issue in question, i.e., femicide. The students also participated in a discussion about the social issue at hand at the end of the intervention. The analysis of the collected data suggests that the teaching-learning method employed in this research is a viable way of teaching the Natural Sciences, especially Chemistry, in an interdisciplinary and contextualized fashion.

Keywords: Forensics; Femicide; Natural Sciences; Teaching-Learning Process.

Resumo: A maneira como as Ciências Naturais têm sido ensinadas na escola por meio de métodos baseados em aulas expositivas, tem se mostrado ineficaz. Por esta razão, muitas formas alternativas de ensinar e aprender têm sido propostas. Este estudo tem como foco o ensino das ciências naturais por meio de atividades investigativas lúdicas no contexto da ciência forense. Propõe uma forma alternativa de ensinar as Ciências Naturais no contexto de questões relevantes para os alunos e a sociedade. Para tanto, utilizou-se um caso de feminicídio para ensinar temas das Ciências Naturais ao abordar uma importante questão social, ou seja, a violência contra a mulher. Esta pesquisa, um estudo de caso de natureza qualitativa, foi realizada no Colégio de Aplicação de Macaé, RJ, Brasil. Suas atividades de ensino-aprendizagem propostas foram realizadas em três aulas consecutivas de 90 minutos na possível promoção do ensino-aprendizagem. Os alunos participantes responderam a questionários pré e pós-intervenção sobre os conceitos científicos abordados nas atividades e a questão social em questão. Os alunos também participaram de uma discussão sobre este último ao final da intervenção. A análise dos dados coletados sugere que o método de ensino-aprendizagem empregado nesta pesquisa é uma forma viável de ensinar as ciências naturais, especialmente químicas, de forma interdisciplinar e contextualizada.

Palavras-chave: Forense; Feminicídio; Ciências Naturais; Processo de ensino-aprendizagem.

Introduction

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The conventional way of teaching the Natural Sciences, i.e., by merely transmitting concepts and theories to students through lectures and having them solve textbook problems, has been pointed as the cause for their lack of motivation and interest in learning these subjects. For this reason, many attempts at improving and changing the teaching of these sciences have resorted to the use of experimentation and contextualization (CORCORAN; ROOD; TROGDEN, 2011; DA SILVA *et al.*, 2020; GOMES *et al.*, 2019; HARDY *et al.*, 2021; KULEVICH; HERRICK; MILLS, 2014; MONFETTE; BLACQUIERE; FOGG, 2011; QUIVE *et al.*, 2021).

While teachers play an active role in lecture-based teaching methods, the students' role is usually reduced to sitting at their desks and listening passively to their teachers, to all intents and purposes disassociated from the teaching-learning process. In this case, student motivation to learn is solely intrinsic, i.e., it has to come from within the students themselves and depends on the teacher's personal characteristics and abilities to secure their interest in the subject at hand (DA *et al.*, 2018). In order to replace or complement the conventional lecture-based method and promote the learning of Natural Sciences in more effective and attractive ways from the students' point of view, different teaching methods are needed, methods whose activities can reflect real-world situations and aim beyond student memorization of concepts and theories (BABINČÁKOVÁ; BERNARD, 2020; CUBILLÁN; MARRERO-PONCE; GONZÁLEZ, 2020; HOFSTEIN, 2017; KOLIL; MUTHUPALANI; ACHUTHAN, 2020). The use of experimentation and investigation can effectively contribute to the teaching of the Natural Sciences as student motivation, interest, and creativity are heightened when students are given the opportunity to see themselves in situations that mirror those experienced by real-world professionals, such as scientists or forensics experts. When properly employed, experimentation can be an important instructional tool for knowledge acquisition and construction (DA *et al.*, 2018; GOMES *et al.*, 2019; HARPER-LEATHERMAN; HUANG, 2019; NABAIS; COSTA, 2017).

Forensics has become highly popular among the general public through TV shows and movies, e.g., *CSI: Crime Scene Investigation* and *Bones*. This field of science encompasses other sciences, such as Chemistry, Physics, and Biology, in an interdisciplinary fashion and can be employed to increase student motivation by means of teaching cases (HARPER-LEATHERMAN; HUANG, 2019). The Brazilian public has learned about forensics especially through media outlets, which often reinforce stereotypes and existing paradigms. For instance, the Eloá affair, a femicide perpetrated by a man named Lindemberg Alves in 2009, was depicted by our mainstream media as a crime of passion committed by a law-abiding citizen who truly

loved his victim. This example exposes the inordinate power of media outlets in normalizing psychopathic jealousy and verbal, physical, and psychological violence against women (ROSSI, 2020).

In Brazil, the legislation deterring and punishing femicide and gender-based violence is the result of unrelenting social activism. This activism climaxed in 2006 when the “Maria da Penha” Law was approved by the Brazilian Congress and later sanctioned by the president. The gender-based concept of domestic violence advanced by this law has been important to protecting women from violence by husbands and partners, children or relatives. This landmark law was complemented in 2015 to include femicide — i.e., the killing of a woman or girl, in particular by a man, because of her gender — as an aggravating circumstance to homicide. This complementation derived from the understanding that gender specificities are obvious in many murders of women (REPÚBLICA, 2015).

Femicide and other forms of gender-based violence do not occur in a vacuum; they are the unwanted result of a culture founded on patriarchal ideologies and systems of male supremacy. Patriarchy is older than Western Civilization; it was already a well-established institution by the time of the Romans. Patriarchy is a system of society or government in which the father or eldest male is head of the family or state. In the family context, the father, husband or eldest male relative commands the lives of his wife, female relatives, children, slaves, and vassals, in addition to having the right of life and death over them. In Rome, the authority of the *pater familiae* over wives, children, and slaves prevailed even over the authority of the state and would last until the death of the patriarch, who could even turn his son into a slave and sell him (KAMP, 2020; PHILLIP LONGMAN, 2014). It is worth noting that patriarchy does not designate the power of the father, but the power of men or the masculine, as a social category. Male supremacy dictated by the values of patriarchy places a greater value on male activities at the expense of female activities; it legitimizes the control of female sexuality, bodies, and autonomy and establishes sexual and social roles in which the masculine has advantages and prerogatives over the feminine (PHILLIP LONGMAN, 2014).

Although patriarchy preceded capitalism in the West, both systems are closely intertwined and mutually dependent in our times. Patriarchy and capitalism are two ways of producing and reproducing life based on relations of domination and expropriation, especially of women’s bodies and autonomy (JOSHI; PRÜGL; NGOUV, 2022; KAMP, 2020; VON WERLHOF, 2007). The growing ‘feminization’ of poverty is the most visible face of today’s marriage between patriarchy and predatory capitalism (MIES, 2007; ROBERTA HAMILTON,

2013); according to estimates, among the world's one billion people living in extreme poverty, 70% are women (MIES, 2007; VON WERLHOF, 2007).

In Brazil, the family institution was modeled after patriarchal archetypes imported through European colonization and adapted to the social conditions existing in the country at the time, i.e., slavery and latifundia (CAULFIELD; SCHETTINI, 2022). Despite the disintegration of rural patriarchy, which occurred to different extents in different regions of Brazil, the patriarchal character has persisted in Brazilian life and politics by way of patronage, nepotism, and 'coronelismo,' i.e., a system of unwritten agreements among local bosses (the colonels) to control the votes of population in return for favors and protection (SANTOS, 2014). For that reason, even in urban areas, authoritarian attitudes regarding the female condition must be understood in relation to the social domination that characterizes traditional Brazilian patriarchy (SANTOS, 2014; SUSAN K. BESSE, 2000).

Since Brazil's colonial times, a woman's status in the family and society has been an indication that the patriarchal family is one of the templates of our social organization. In fact, Brazilian women only conquered the civil rights guaranteed to men in the first decades of the 20th century (SANTOS, 2014; SHWALB; SHWALB, 2014). Created in 1916, Brazil's patriarchal and paternalistic Civil Code stated that married women could only work with the permission of their husbands. Although a new constitution guaranteed the vote of women in 1934, their work was only regulated by the Consolidation of Labor Laws a decade later. Only in 1962 was Brazil's Civil Codex amended to allow married women to work without their husbands' permission (SUSAN K. BESSE, 2000).

Brazil's 1988 Constitution and 2002 Civil Code, which replaced the 1916 Civil Code, consolidated some women's rights in society. In the new Civil Code, the family is no longer governed by the paternal power as in the feudal era but by that of the *pater familiae*, presupposing shared power between the parents. Some terms found in the previous Code were changed in order to reduce the androcentric language contained therein, e.g., "every man" was replaced with "every person." Brazil's 1988 Constitution also established a legal-political framework for the institutionalization of human rights and the principle of equality between men and women. Its Article 226/Paragraph 5 states, "The rights and duties related to the conjugal society are exercised equally by the man and the woman" (SUSAN K. BESSE, 2000; Dias, 2004; PANDJIARJIAN, 2003; ROCHA, 2003).

Despite the aforementioned advancements in Brazil's legislation regarding women, femicides and other forms of violence against women persist because they are part of a broader sociocultural structure that supersedes the perpetrators' fear of punishment. For this reason,

women's rights movements have acknowledged that laws by themselves cannot change Brazil's pervasive machismo and resulting violence against women in the country. There is a consensus that a concerted effort, in which formal education plays an important role, is direly needed to change Brazil's patriarchal culture.

It is well established that formal education or school-based learning is not the only way we learn. Informally, education takes place everywhere: at home, in the streets, in sports, in games with friends, at the movies, in visits to museums, and so forth. In this sense, teachers, as mediators of scientific knowledge, are not only responsible for imparting structured knowledge but also for shedding light on their students' self-made discoveries and helping them to make sense of informally-gathered information and critically appraise its value. For that reason, the school is a privileged space for dealing with and addressing topics such as violence against women as it enables students to reflect on informally acquired information and long-standing social conventions and beliefs. In so doing, the school is a vector for change in society regarding gender equality as it promotes dialog and discussion about sensitive issues and urgent social ills, e.g., gendered violence and gender inequality, thus contributing to their mitigation and, ultimately, resolution.

In light of the aforementioned, this study aimed at discussing and assessing the participating students' ideas about femicide and other forms of violence against women within the framework of the Natural Sciences. At the end of this intervention, the participants were expected to have acquired knowledge of the social issue in question as well as of specific concepts and theories from the Natural Sciences and, as a result, acknowledged the importance of the latter to their lives and society.

METHOD

This intervention-research may be characterized as a case study of a qualitative nature. A qualitative case study aims at investigating social and educational phenomena in depth within their real-life contexts (Charkoudian et al., 2008; Duit & Tesch, 2010; Figueiredo, B. S., Nunes, M. R., & Pinheiro, 2019). To this end, it employed a fictitious crime (forensic investigation) to promote the construction of student knowledge of the Natural Sciences, mainly of Chemistry, while exposing them to relevant social issues (femicide and gender-based violence) and showing them the importance of knowledge of the Natural Sciences to their own lives and society.

The research was conducted at Colégio de Aplicação (CAp), a public institution linked to the Board of Education in Macaé, RJ, Brazil in the second half of 2019. Twenty-six students (70% female; 26% male; 4% other) from two Science laboratory classes, aged between 14 to 19 years participated in the study. Cap already houses a collective organized by its female students — named “Sementes” (“Seeds”) as a tribute to the late feminist and activist Marielle Franco —, whose mission is to discuss issues regarding women and the society in which they live. As CAp’s curriculum had already embraced contextualization and interdisciplinarity before the intervention, its faculty and students were generally open to discuss social issues, such as gender-based violence, its causes and consequences.

The data were collected by means of pre- and post-intervention questionnaires (with open-ended and multiple-choice questions). The pre-intervention questionnaire comprised 15 questions aimed at assessing the participating students’ previous knowledge of the Natural Sciences and Forensics as well as their perceptions of these sciences. The post-intervention questionnaire contained 25 questions assessing the participants’ learning of specific scientific concepts and theories as well as their perceptions of the social issue in question, *i.e.*, femicide and gender-based violence. The data on the participating students’ science knowledge and concepts and ideas about the social issue in question were collected only after the intervention because the researchers feared that doing so before hand could interfere with the problem-solving process. Data on the participants’ concepts and ideas about femicide and gender-based violence were also collected during the post-intervention discussion in which the aforementioned information about Brazil’ spatriarchal culture, past and current Civil Code, and so forth was presented to and discussed with the participants.

Intervention

The teaching-learning activities included in the proposal were organized as a teaching sequence of four 50-minute classes as follows:

Class 01. The participating students were given a teaching case/problem-situation (Figure 1), *i.e.*, a fictitious crime story (a femicide), and asked to conduct a criminal investigation, analyze the evidence, and identify its perpetrator.

A 23-year-old black woman was stabbed to death in Joinville. At the crime scene, DNA samples were collected from underneath the victim's nails. Fingerprints were also collected from a glass thought to have been used by the murderer. The crime happened after a fight between Maria Beatriz (Rafael's ex-girlfriend) and Marcela (victim; Rafael's then girlfriend). According to witnesses, the fight was caused by Maria Beatriz's suspicion that Rafael had betrayed her with Marcela while he was still her boyfriend. During the fight, Marcela broke up with Rafael (who already had a police record for violence against both women). Some witnesses also reported that Rafael had threatened to kill Marcela. A second man, José Henrique, is also a suspect as he had taken Marcela home after the fight and had been seen leaving the victim's house early in the morning on the following day.

Figure 1. Teaching case used in the intervention.

After the 'crime,' i.e., the teaching case, was discussed, the participating students were introduced to forensic methods as related to concepts of the Natural Sciences, namely, intermolecular forces in fingerprint identification, chemical bonds, ionic charge, nitrogenized bases, and ion mobility in DNA identification through electrophoresis, and luminol chemiluminescence reactions as informed by Bohr's atomic model in blood trace detection.

Class 02. The experimental activities were conducted at CAP's science laboratory. The students received instructions about the material, reagents, and analytical method to be employed to solve the teaching case. These activities included fingerprint identification using the iodine vapor method, DNA identification by gel electrophoresis, detection of footprints using black powder, blood detection using the Kastle-Meyer method, and estimation of time of death using Equation 1 and the shoe size using Equation 2 (CRESSWELL; LOUGHLIN, 2015; GOMES *et al.*, 2019; HARPER-LEATHERMAN; HUANG, 2019; NABAIS; COSTA, 2017).

$$H = \frac{(36.6 - C)}{T} \quad (\text{Eq. 1})$$

Where H = time since death (hours); °C = temperature of body when found (Celsius) and T = body temperature decrease rate after death (0.67 °C/h)

$$S = \frac{(5p + 28)}{4} \quad (\text{Eq. 2})$$

where S is the shoe size and p is the size of the bare foot in centimeters.

Classes 03 and 04: The simulated crime scene contained the contours of a body drawn on the floor with chalk, a knife smeared with (bovine) blood, (bovine) blood spots on the floor,

pieces of paper with fingerprints, and paper strips with a DNA sequence (Figure2). Beside the ‘crime scene’ were some equipment needed to collect and analyze the evidence, e.g., a camera, envelopes and labels for sample identification, metal tongs, surgical gloves, an iodine chamber, swabs, Kastle-Meyer reagent, and hydrogen peroxide.



Figure 2. Crime scene.

After the ‘crime scene’ was presented to the students, they were divided into four groups. The students collected samples of the blood on the knife and floor by means of swabs moistened with saline solution. They also placed and sealed the fingerprint samples and DNA strips in plastic bags. Then, they returned to the laboratory to analyze these pieces of evidence. **Time of Death:** at the laboratory, the students were provided with supplementary information on the ‘crime,’ as if gathered by other police personnel (Figure 3). With this information in hand, the students were able to calculate the time of death using Equation 1.

According to the forensic police, the body was found at 10 a.m. Its temperature was 35.28 °C. Suspect #3 clocked in at the supermarket where he works (about 8 km from the victim’s house) at 7:30 a.m. and, according to surveillance camera footage, stayed there until lunch time (12:12 p.m.).

Figure 3. Supplementary information on the ‘crime.’

Footprint size. The students took the piece of paper with a footmark to the laboratory, where they proceeded to reveal the footprint using black powder (Figure 4). In addition, they were provided with the three suspects shoe sizes (S01 = 36 cm; S02 = 39 cm; S03 = 42 cm). Once measured, the suspect's shoe size was calculated using Equation 2.



Figure 4. The suspect's footprint.

RESULTS AND DISCUSSION

The answers to the pre-intervention questionnaire indicated that 90% of the participants considered it indispensable to study the Natural Sciences and 81% believed that this knowledge could be applied to improve human life, which suggests their positivistic stance towards the natural sciences and their role in society. On the other hand, 61% of the respondents regarded the teaching of the Natural Sciences as important, albeit boring, which explains the fact that 31% reported that they only took science courses because they were mandatory. This lack of motivation may be attributed to the predominance of ineffective teaching methods in schools, in which science topics are taught by means of lectures, divorced from the students' reality and real-life applications of this knowledge. Furthermore, the prevalence of lecture-based teaching methods in the Natural Sciences classroom may contribute to the students' disincentive in developing skills and acquiring conceptual knowledge.

As to the teaching of Chemistry at CAP, which has a science laboratory, most of the participating students (88%) reported they had never had laboratory classes, regardless of the fact that experimental investigation is *sine qua non* to the study and teaching of the Natural

Sciences and the development of specific technical skills. Therefore, the sole use of lectures to transmit knowledge to students and merely aiming at their memorization of concepts and equations do not suffice to the teaching of the Natural Sciences(AIRTON, 2011).

When asked what they thought of Forensic Chemistry and criminal investigations, all of the participating students considered them interesting. For this reason, Forensics may constitute a good way of teaching and learning about the Natural Sciences in the context of real-world issues and, thus, demonstrating the importance of science knowledge to society(CHARKOUDIAN *et al.*, 2008; HARPER-LEATHERMAN; HUANG, 2019).

Before the intervention, the participants were asked whether they had any knowledge of Forensics and, if so, to give examples of forensic techniques to which the knowledge of the Natural Sciences were applied. Some of their answers were: “*It is used in crime scenes;*” “*To find out who the criminal is, for instance;*” “*To detect fingerprints, find out how the victim died, help to solve the crime, ballistics;*” “*Murder;*” “*It may be used to solve a crime by identifying fingerprints, DNA, blood spots, etc., and in DNA testing;*” and “*Collecting DNA at the crime scene to find out who the murderer is,*” which shows that their knowledge of the relationship between Forensics and the Natural Sciences was reasonable, albeit superficial, probably informed by TV show and movie scenes in which fictitious pieces of crime scene evidence were analyzed at laboratories.

In the same vein, when asked about body fluids that could be employed in DNA testing, the participants cited blood (85%), saliva (77%), semen (54%), urine (20%), and sweat (15%).When inquired about their knowledge of Forensic Science techniques, the students reported some knowledge of DNA testing (96%), fingerprint identification (92%), and blood identification or serology (62%). Techniques, such as ballistics (31%) and gel electrophoresis (35%), were less known, probably because these techniques are less frequently depicted in crime investigation movies and TV shows due to their storytelling complexity. For that reason and because of its feasibility, we chose the gel electrophoresis technique as one of the hands-on activities for the intervention.

As regards their previous knowledge of Basic Chemistry as applied to Forensics, some concepts such as intermolecular interactions (e.g., Van der Waals forces and dipole-dipole forces) were only properly understood by 27% and 23% of the participants, respectively. Moreover, while half of the students were able to define the Dalton and Bohr atomic models, only 30% and 20% were capable of correctly explaining the Thomson and Rutherford atomic models, respectively. When asked about the relationship between atomic models and the luminescence effect of luminol, only 10% of the students could link it to the Rutherford-Bohr

model, which corroborates the idea that the Natural Sciences are largely taught in isolation from reality and practical applications.

The participants' answers to the pre-intervention questionnaire per se justify the adoption of non-conventional methods for the teaching of the Natural Sciences that make use of interdisciplinarity and contextualization as proposed in this intervention-research.

After the intervention, the participating students were asked about the relevance of Forensics to society; all of them agreed that it was relevant and 55% of them reported that it could improve the lives of all citizens. Notwithstanding their overall approval of Forensics, only 14% of the students claimed that it might also be used to promote impunity, a pervading feeling in today's societies, especially in Brazil, in which the police are underfunded and mistrusted by 60% of the population (FREIRE, 2020) compounded by the fact that our popular media over-report crimes but seldom follow up on their resolution or retribution. This feeling of impunity and distrust of law enforcing institutions was also present during the post-intervention discussion about the social issue in question in which some students pointed to the machismo and racism permeating these institutions in Brazil. As regards the presence of structural racism in Brazil's judicial system, Figueiredo, Nunes, and Pinheiro (2019) claim that because it was constructed on racist theoretical and scientific bases, Brazil's Penal Code "has been applied in the country to repress, segregate, and criminalize black people, who have experienced all forms of racism present in the nation's structures since its colonial days."

The majority of the participants reported that the intervention enjoyable, which was corroborated by 91% of them considering Forensics an appropriate field of knowledge for the teaching of the Natural Sciences. As compared to 61% that responded not enjoying their science classes before the intervention, this result suggests that the proposed teaching method succeeded in increasing student motivation. This increase may be attributed to the way the scientific concepts and theories were contextualized during the proposed intervention, which favored student autonomy and clearly indicated the relationship between science and society to the participants.

As regards the conceptual explanations provided by the teacher during the intervention, 70% and 30% of the participants considered them excellent and good, respectively. Before the intervention, only 4% and 42% of the students had done so, respectively. Considering that the participating teacher's explanatory ability was the same, this change most likely reflects an improvement in the students' motivation and ability to understand the explanations provided by the teacher in the context of the teaching case in question. The students' reported difficulty in learning concepts and theories of the Natural Sciences also changed, which corroborates the

above analysis. The percentage of students reporting high difficulty (23%) and low difficulty (58%) in acquiring this knowledge before the intervention changed to 0% and 73%, respectively, after the intervention. Several researchers have shown the importance of teaching Chemistry and the Natural Sciences in a challenging, motivating, and problematized manner in order to encourage students to construct their scientific knowledge. Scientific knowledge should be presented to students in ways that enable active student participation and promote their understanding of, sense of belonging to, and responsibility towards their society and the environment (DUIT; TESCH, 2010; KOLIL; MUTHUPALANI; ACHUTHAN, 2020; QUIVE *et al.*, 2021).

In order to assess the effectiveness of the proposed teaching method as regards the students' learning of concepts and theories related to forensics and the natural sciences, the participants were asked to describe one of the techniques employed during the intervention and the scientific concepts associated with it. Their answers indicate that they were able to understand the relationship between forensics and the Natural Sciences, albeit sometimes superficially: *"To develop footprints and fingerprints through incomplete combustion of paraffin and iodine powder;" "Luminol, development of fingerprints and Kastle-Meyer reaction;" "Fingerprint development through iodine vapor reaction with body fat;" "We used a [forensic] technique to develop the murderer's fingerprint that comprised a chemical reaction between the lipid present in the fingerprint and a reagent;"* and *"We developed footprints and fingerprints using the incomplete combustion of paraffin and iodine power, respectively."* In addition, about 40% of the students correctly associated fingerprint development to intermolecular interaction as compared to 12% before the intervention, which suggests that learning occurred. The occurrence of student learning is also corroborated by the higher percentage of participants that chose Bohr as the atomic model that best explained the luminescence effect of luminol after the intervention as compared to that before the intervention (57% and 8%, respectively).

The fact that 70% of the participants identified as female may have contributed to the students' willingness to discuss the social issue in question. When asked to choose how much they knew about the "Maria da Penha" law, 70% responded having basic or adequate knowledge of it. As to their knowledge of the law against femicide, 78% of the respondents reported having no knowledge or basic knowledge of it, which suggests that the participants were less acquainted with the femicide law. The discrepancy between the students' acquaintance with the "Maria da Penha" Law and the femicide law may be due to the latter being more recent.

In order to check whether the students could tell how the “Maria da Penha” law differed from the femicide law, they were asked to identify their dissimilarities. Their answers indicated that they knew how these laws differed, despite only a few of them having stressed the fact that the femicide law stipulates more severe punishment than that prescribed for homicide: *“I think the ‘Maria da Penha’ law protects women by keeping their aggressors away from them while the femicide law establishes the punishment for their murderers, which is harsher than that for homicide;”* *“The ‘Maria da Penha’ law protects women from domestic violence while the femicide law is related to murders of women;”* *“One punishes violence against women, be it physical, mental or verbal, and the other punishes an individual that murders a woman simply because of her gender;”* and *“The ‘Maria da Penha’ law deals with domestic violence and the femicide law with murders of women.”*

When asked specifically about femicide, the participants showed adequate knowledge of this criminal offence and pervasive deleterious social phenomenon: *“Deaths directly linked to the power structure and oppression to which women are submitted;”* and *“All sorts of violence against women resulting in death.”* However, not all students were able to understand its connection to murder: *“A crime against women marked by verbal, physical, and psychological violence;”* *“Hate crime towards women;”* and *“When a man assaults a woman, even psychologically or physically.”*

In order to assess the role of the Natural Sciences (Physics, Chemistry, Mathematics, Biology, etc.) in the fight against machismo, gender-based violence, and femicide, the participants were asked about CAp faculty’s initiatives in this regard. While approximately half of the students reported having previously participated in discussions about machismo and gender-based violence during science classes, 44% had never been exposed to these topics at school, which corroborates the relevance of teaching the Natural Sciences in integration with society’s broader issues. In addition, to assess the impact of this kind of discussion on their lives, the participants were asked whether they had been victims of any kind of physical or psychological violence perpetrated by a close male friend or relative (female students) or had witnessed or heard of any such cases (all students). Nine percent of the students reported having been victims of gender-based violence and 87% of them reported knowing someone who had, a result that shows how pervasive this deleterious phenomenon is in Brazil.

When asked to choose their level of acquaintance with Brazilian law enforcing agencies specialized in protecting women from domestic violence, 65% of the participants reported little knowledge of these agencies and their scope and practices. If we extrapolate to society, the fact that 87% of the participants reported knowing someone or having heard of a victim of gender-

based violence, their deficient knowledge of these agencies may imply that much of this kind of violence goes unreported and its victims do not get proper support.

As aforementioned, at the end of the intervention, the researchers conducted a discussion with the participants about gender roles and gender-based violence. They were asked why men felt entitled to harass and assault women in Brazil. Many students alluded to machismo and patriarchy as the most important factors: *“Because they know they won’t be punished. Violence against women’s bodies is not considered a heinous practice since they’re lesser beings;”* *“Because they’ve been raised to believe they have power over women’s bodies to do whatever they please;”* *“They believe they are entitled to harass women because of their higher standing in society;”* and *“Because they are sexist and we live in a patriarchal society that regards women as inferior to men.”* Some students also put the blame on the judicial system and women’s economic dependence on men: *“Society’s machismo and toxic masculinity assure them they will not be punished, which is often the case;”* *“The cases are often shelved or are never reported or are minimized by the police;”* and *“In my opinion, many women don’t report the perpetrators to the police because they depend economically on them; they have nowhere to go or are threatened to not report the violence to the police.”*

When asked to think about the available tools to fight gender-based issues and gender-based violence, 78% of the participants considered education the best way to deconstruct machismo, which naturalizes and perpetuates femicide and all sorts of gender-based violence in Brazil’s cultural context. As to the appropriateness of discussing femicide and gender-based violence through forensics, 74% of the students agreed. It should be noted that addressing these social issues when teaching the Natural Sciences also brings forth other gender-related issues and prepares the students for a fuller life in society. In accordance with the views expressed by Brazilian feminists, education, especially formal or structured education, is the most promising tool to fight sexism, machismo, and gender-based violence in our society, given that punishment by itself has not sufficed to mitigate this deleterious phenomenon, pervasive in Brazilian society and culture.

CONCLUDING REMARKS

This research has shown that student motivation and interest in learning the Natural Sciences can be increased by employing methods that promote interdisciplinarity and contextualization. According to the participants, the knowledge of the Natural Sciences was successfully taught by means of the proposed teaching case, i.e., a crime scene investigation. Besides acquiring knowledge of these sciences, the students were given the opportunity to

develop laboratory and investigative skills. In addition, the way that teaching case was crafted promoted the students' knowledge and awareness of a social issue of great consequence in Brazil, i.e., femicide and gender-based violence.

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References

- BABINČÁKOVÁ, Mária; BERNARD, Paweł. Online experimentation during covid-19 secondary school closures: Teaching methods and student perceptions. **Journal of Chemical Education**, vol. 97, no. 9, p. 3295–3300, 2020. <https://doi.org/10.1021/acs.jchemed.0c00748>.
- CAULFIELD, Sueann; SCHETTINI, Cristiana. Gender and Sexuality in Brazil since Independence. **Oxford Research Encyclopedia of Latin American History.**, 2022. DOI 10.1093/acrefore/9780199366439.013.296. Available at: <https://oxfordre.com/latinamericanhistory/view/10.1093/acrefore/9780199366439.001.0001/acrefore-9780199366439-e-296>.
- CHARKOUDIAN, Louise K.; HEYMANN, Jared J.; ADLER, Marc J.; HAAS, Kathryn L.; MIES, Kassy A.; BONK, James F. Forensics as a gateway: Promoting undergraduate interest in science and graduate student professional development through a first-year seminar course. **Journal of Chemical Education**, vol. 85, no. 6, p. 807–812, 2008. <https://doi.org/10.1021/ed085p807>.
- CORCORAN, K. Blake; ROOD, Brian E.; TROGDEN, Bridget G. Chemical remediation of nickel(II) waste: A laboratory experiment for general chemistry students. **Journal of Chemical Education**, vol. 88, no. 2, p. 192–194, 2011. <https://doi.org/10.1021/ed100519t>.
- CRESSWELL, Sarah L.; LOUGHLIN, Wendy A. An Interdisciplinary Guided Inquiry Laboratory for First Year Undergraduate Forensic Science Students. **Journal of Chemical Education**, vol. 92, no. 10, p. 1730–1735, 2015. <https://doi.org/10.1021/acs.jchemed.5b00183>.
- CUBILLÁN, Néstor; MARRERO-PONCE, Yovani; GONZÁLEZ, Alicia Inciarte. Integration of algebra and chemistry concepts with molecular descriptors: A problem-based learning exercise. **Educacion Quimica**, vol. 30, no. 2, p. 14–26, 2020. <https://doi.org/10.22201/fq.18708404e.2019.2.65090>.
- DA, Murilo S; JULIÃO, S; RODRIGUES, Silvia H B G; ANDRADE, Lucia B S; MELO, Luisa C. Teaching Chemical Equilibria: A Contextualized Scientific Method and Forensic Chemistry Class. **Journal of Laboratory Chemical Education**, vol. 6, no. 5, p. 148–155, 2018. DOI 10.5923/j.jlce.20180605.02. Available at: <http://journal.sapub.org/jlce>.
- DA SILVA, Andreza Miranda Barata; SERRÃO, Naiany Oliveira; DE GUSMÃO CELESTINO, Gustavo; TAKENO, Mitsuo Lopes; ANTUNES, Nicanor Tiago Bueno; IGLAUER, Stefan; MANZATO, Lizandro; DE FREITAS, Flávio Augusto; MAIA, Paulo José

- Sousa. Removal of rhodamine 6G from synthetic effluents using *Clitoria fairchildiana* pods as low-cost biosorbent. **Environmental Science and Pollution Research**, vol. 27, no. 3, p. 2868–2880, 2020. <https://doi.org/10.1007/s11356-019-07114-6>.
- DUIT, Reinders; TESCH, Maike. On the role of the experiment in science teaching and learning – Visions and the reality of instructional practice. **Proceedings of the 7th International Conference on Hands-on Science.**, no. January 2014, p. 17–30, 2010. Available at: <https://www.researchgate.net/publication/228588546%0A>.
- GOMES, Josiele Viana; DA SILVA, Fabrício Valentim; DO CARMO, Dominique Fernandes de Moura; MAIA, Paulo José Sousa. TV series of criminal investigation in chemistry teaching through of research and ludic experimentation. **Periódico tchê química**, vol. 16, no. 32, p. 919–929, 2019.
- HARDY, John G.; SDEPANIAN, Stephanie; STOWELL, Alison F.; ALJOHANI, Amal D.; ALLEN, Michael J.; ANWAR, Ayaz; BARTON, Dik; BAUM, John V.; BIRD, David; BLANEY, Adam; BREWSTER, Liz; CHENELER, David; EFREMOVA, Olga; ENTWISTLE, Michael; ESFAHANI, Reza N.; FIRLAK, Melike; FOITO, Alex; FORCINITI, Leandro; GEISSLER, Sydney A.; WRIGHT, Karen L. Potential for Chemistry in Multidisciplinary, Interdisciplinary, and Transdisciplinary Teaching Activities in Higher Education. **Journal of Chemical Education**, vol. 98, no. 4, p. 1124–1145, 2021. <https://doi.org/10.1021/acs.jchemed.0c01363>.
- FREIRE, Sabrina. 21% confiam totalmente na polícia; 16% não confiam. **Poder360**. Disponível em: <https://www.poder360.com.br/brasil/21-confiam-totalmente-na-policia-16-nao-confiam/>. Acesso: 13/09/2022.
- HARPER-LEATHERMAN, Amanda S.; HUANG, Ling. Introduction to Teaching Chemistry with Forensic Science. **ACS Symposium Series**, vol. 1324, p. 1–11, 2019. <https://doi.org/10.1021/bk-2019-1324.ch001>.
- HOFSTEIN, Avi. The Role of Laboratory in Science Teaching and Learning. **Science Education**, , p. 357–368, 2017. https://doi.org/10.1007/978-94-6300-749-8_26.
- JOSHI, Saba; PRÜGL, Elisabeth; NGOUV, Muy Seo. Gender mainstreaming in a hybrid state. Entanglements of patriarchy and political order in Cambodia ’ s food security sector. In: JOANNA BOURKE MARTIGNONI, CHRISTOPHE GIRONDE, CHRISTOPHE GOLAY, ELISABETH PRÜGL, Dzodzi Tsikata (ed.). **Agricultural Commercialization, Gender Equality and the Right to Food**. 1st ed. London: [s. n.], 2022. p. 290. <https://doi.org/10.4324/9781003202004-8>.
- KAMP, John B. Patriarchy and Gender Law in Ancient Rome and Colonial America. **The Iowa historical review**, vol. 8, no. 1, p. 43–57, 2020. <https://doi.org/10.17077/2373-1842.1072>.
- KOLIL, Vysakh Kani; MUTHUPALANI, Sharanya; ACHUTHAN, Krishnashree. Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. **International Journal of Educational Technology in Higher Education**, vol. 17, no. 1, 2020. <https://doi.org/10.1186/s41239-020-00204-3>.
- KULEVICH, Suzanne E.; HERRICK, Richard S.; MILLS, Kenneth V. A discovery chemistry experiment on buffers. **Journal of Chemical Education**, vol. 91, no. 8, p. 1207–1211, 2014. <https://doi.org/10.1021/ed400377a>.
- MIES, Maria. Patriarchy and accumulation on a world scale - Revisited (Keynote lecture at the Green Economics Institute, Reading, 29 October 2005). **International Journal of Green Economics**, vol. 1, no. 3–4, p. 268–275, 2007. <https://doi.org/10.1504/IJGE.2007.013059>.
- MONFETTE, Sebastien; BLACQUIERE, Johanna M.; FOGG, Deryn E. The future, faster: Roles for high-throughput experimentation in accelerating discovery in organometallic chemistry and catalysis. **Organometallics**, vol. 30, no. 1, p. 36–42, 2011. <https://doi.org/10.1021/om1010319>.
- NABAIS, J. M. Valente; COSTA, Sara D. A Forensic Experiment: The Case of the Crime at the Cinema. **Journal of Chemical Education**, vol. 94, no. 8, p. 1111–1117, 2017.

<https://doi.org/10.1021/acs.jchemed.6b00942>.

PHILLIP LONGMAN. The Return of Patriarchy. **Foreign Policy JSTOR**, no. 153, p. 56–60, 2014. .

QUIVE, Lucas Gil; LEANDRO, Sérgio; BANDALI, Esaú Carlos; GUEZE, Geraldo Alfredo; JOÃO, Domingos Augusto; GOMUNDANHE, Almeida Meque; NEUANA, Neuana Fernando; MACUVELE, Domingos Lusitâneo Pier. Exploring materials locally available to teach chemistry experimentally in developing countries. **Education for Chemical Engineers**, vol. 34, p. 1–8, 2021. <https://doi.org/10.1016/j.ece.2020.09.004>.

REPÚBLICA, Presidência da. Femicídio - lei nº 13.104, de 9 de março de 2015. 2015. Available at: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2015/lei/113104.

LEI Nº 13.104%2C DE 9 DE MARÇO DE 2015 do Decreto-Lei nº, no rol dos crimes hediondos.

ROBERTA HAMILTON. **The liberation of women A Study of Patriarchy and Capitalism**. Vol 29. Abingdon, Oxon: [s. n.], 2013. <https://doi.org/10.1007/978-1-137-09848-1>.

ROSSI, Túlio Cunha. Love speech on the violence against women: A sociological analysis of “Quem matou Eloá.” **Revista Brasileira de Ciências Sociais**, vol. 35, no. 102, 2020. <https://doi.org/10.1590/3510220/2020>.

SANTOS, Martha S. Recreating Patriarchy in Northeast Brazil: Widows, Property Rights, and Gender Inequality in the Backlands of Ceará, 1845–1889. **Luso-Brazilian Review**, vol. 51, no. 2, p. 150–169, 2014.

SHWALB, David W; SHWALB, Barbara J. Fatherhood in Brazil, Bangladesh, Russia, Japan, and Australia. **Online Readings in Psychology and Culture**, vol. 6, no. 3, p. 1–21, 2014. <https://doi.org/10.9707/2307-0919.1125>.

SUSAN K. BESSE. Restructuring Patriarchy: The Modernization of Gender Inequality in Brazil, 1914-1940. **Signs**, vol. 25, no. 2, p. 564–566, 2000. .

VON WERLHOF, Claudia. No critique of capitalism without a critique of patriarchy! Why the left is no alternative. **Capitalism, Nature, Socialism**, vol. 18, no. 1, p. 13–27, 2007. <https://doi.org/10.1080/10455750601164600>.

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