

A quick look at Implementing Epigenetics in Brazilian High School Biology Curriculum

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Abstract. Epigenetics is an emerging area that studies the extra layer of information on top of the DNA and how it affects gene regulation. This discipline is predicted to be more than 20% of genetics academic importance in 2029 and is required in the Brazilian Nacional Exam of High School (ENEM). This growing attention is due to discussions around environmental and lifestyle impacts on genome and phenotypes, and inheritance. In this way, this observational retrospective study investigated the theme through research on Web of Science, Google Scholar and Scopus, at first using words like “epigenetic”, “school”, “curriculum” and “education” to find literature. And aimed to elaborate on topics of epigenetics to be implemented in Brazilian schools through approaches that possibility students to be more interested in genetics. This article also considers the necessity to qualify teachers better around the theme and defends the demand for didactic books as a helpful complement to in-class education.

Keywords. Biology, epigenetics, secondary curriculum, humanizing pedagogy

1. Introduction

Promoting curriculum is essential to construct an academic environment for secondary students now and in the next generations. Introducing Epigenetics in school is necessary for students to keep up with reliable scientific information as it is a science that already has substantial public circulation [1]. Furthermore, this rapidly emerging biology topic is predicted to be part of 20.7 % of genetics academic importance until 2029 [2]. Although this science requires molecular comprehension of mechanisms, it has a strong interdisciplinary nature and various applications, factors that are required in Next Generational Science Standards (NGSS) [3]. So how does the high school curriculum stimulate students to exercise their critical thought around new biology topics? Since students show more interest in subjects about Health (30%) and align everyday life more with this area in biology (57,9 %) [4].

1.2 A quick review on Epigenetics

Epigenetics is a term invented by Conrad Waddington in the 1940s, the prefix “Epi” in Greek means above. Thus, the nomenclature already elucidates that it is a study about interactions before DNA [5],[6]. Epigenetics is an emerging area that

investigates meiotically and mitotically heritable and reversible changes in patterns of gene expression that do not affect the primary sequence of DNA [7]. Besides that, these changes in gene expression impact cytoplasmic elements, which prompt changes in the phenotype [8]. The main epigenetic regulatory mechanisms known are DNA methylation, histone modifications, non-coding RNA, and variation in chromatin and microRNAs. Most of these mechanisms induce or repress each other, leading to cell phenotype [9],[10].

1.3 Habits and Epigenetics

The debate around nutrition and epigenetics is robust and growing. The study by Anderson et al. and others (2012)[11] clarify that micronutrients like folate, choline, betaine and other B vitamins play an essential role in the one-carbon metabolism, a cyclical cellular process that has S-adenosylmethionine (SAM) as one of the products, being the last-mentioned a primer methyl donor for DNA methylation. Similarly, there is a strong relationship between exercise and epigenetics regulatory mechanisms. For instance, studies have shown that six months of aerobic exercise can change the DNA methylation of skeletal muscles and adipose tissues and that microRNAs are expressed differently in individuals with different maximal oxygen consumption (VO2max) [12],[13].

1.4 Genetics on Brazilian school curriculum

Biology in Brazil's school curriculums has been developing analogously to producing knowledge in the field. However, when it comes to genetics, there is a crucial demand to improve the teaching and learning process and to catch the students' interest in classes, considering interest here as bringing personal affection by students to a specific topic [14]. Some works evaluate that this is happening due to the complexity and disconnection of the topics from students' reality [15],[16],[17].

The Brazilian curricular document, Nacional Curriculum Parameters (PCN)[18], emphasises the need for an update on Brazilian education, which is also an essential part of the nature of science. This update mentions Genetics substantially, considering that four of six structural themes of Biology in secondary school, or Ensino Médio, involve this area. In the document, manipulation of DNA in food, mutation and genetic variability, genetic anomalies of cancer, detection and treatments, the debate of genetic manipulation, evolution and population genetics are recommended in detail. Implementing Epigenetics in school could grasp all of these topics, also assuming the requisite expected by NGSS, "Gather and synthesise information about technologies that have changed the way humans influence the inheritance of desired traits in organisms" [3]. Furthermore, Epigenetics is being evaluated in the Nacional Exam of High School of Brazil (ENEM) and other universities' entrance exam test, although it is still not dispersed in schools around Brazil [19].

1.5 Humanizing Pedagogy on the Implementation of Epigenetics

Humanizing pedagogy postulates the necessity to resonate with the content. As the student can relate the classes to his own experiences, making concrete associations gets easier. Also, having part of the knowledge within empowers the individual, enabling personal and collective self-actualisation [20],[21]. So, if losing interest in the genetics discipline happens due to disconnection with their realities, it is essential to keep an eye on a humanizing pedagogy framework to complete the teaching and learning process effectively. This can be implemented by a culturally responsive education and strategic teaching, using more tools than just didactic books in classes [22].

In this way, where can epigenetics enter the biology curriculum? A study from Gericke and Ewen (2023)[6] that synthesises epigenetics experts'

opinions and revisions indicates that it fits better in genetic classes, especially in explaining gene regulation, but can also be taught with ecology, health, evolution, human biology and diseases. This fascinating emerging field is already part of some Brazilian high school student's lives. Although it is equivalent to only three of six didactic books studied by Quaresma (2022)[19], still, the teacher must be qualified to teach this theme appropriately. Also, many professors declare that they do not know or feel secure to teach epigenetics with their graduation baggage [6],[19], explaining a need to implement epigenetics more elaborately and integrally, not just in schools but in universities too. Thus, this article aims to cite topics of epigenetics that could be implemented in the high school biology curriculum, without being a burden for teachers and students, through a humanising pedagogy eye.

2. Research Methods

The present research is an observational retrospective study about better implementing epigenetics in the Brazilian biology curriculum. After determining the question and title, the first step was to choose keywords and combine them in phrases. After noticing the frequency of the words, the second step was to search for them in Google Academic, Scopus and Web of Science. The most used words were "epigenetic", "genetic", "school", "curriculum", "biology", and "education", both in Portuguese (Brazil) and English. Moreover, the most researched phrases were "epigenetics on school curriculum", "genetics on school biology", "humanizing pedagogy", "update on biology curriculum", "epigenetic mechanisms", "nutrition and epigenetics", and "exercise and epigenetics". After that, the next step was choosing articles and books, evaluating accuracy with the search, amount of citing and/or recent publishing date, Also, some papers were collected from other authors' references.

The work from Gericke and Ewen (2023)[6] was the primary reference, considering that the question was very similar to the one from the current study. They made a Delphi study evaluating different experts' opinions on Epigenetics and reaching a consensus between some debates on epigenetics. The scientists delimited interesting approaches, contents and years of implementation.

2.1 Problems Found

The biggest challenge was needing more work on epigenetics in Brazilian biology schools. The

exclusive found was from Quaresma et al. (2022)[19], “Analyses of the Content of Epigenetic Approaches on Biology Didactic Books for High School”, Which added a lot to this study, even focusing on the didactic books.

3. Results

One of the most relevant gains of implementing epigenetics in the biology curriculum is the development of critical thinking about health and social environmental conditions by students for themselves and society. This is an essential requisite for the organ that labour for quality education in Brazil: The Ministry of Education and Culture (MEC), which claims that the contribution of learning should face not just technical knowledge, thus developing interpretation of natural facts, comprehension of procedures of social and professional daily basis , and creating critical thinking.

Despite being a relatively new debate, learning epigenetics mechanisms are essential for understanding differentiation in developmental biology [7]. And also for comprehending how its patterns are inherited by daughter cells through mitosis [5], collaborating to understand evolution and showing its interdisciplinary face in various ways. Both PCN and the Nacional Common Curricular Basis (BNCC)[23], which is a normative curricular document for public and private schools to consider when structuring the curricular and pedagogical proposes, highlight the importance of debating new themes, stimulate the active participation of students and allow them to argue and act in challenges proposed.

Implementing a new discipline is something other than straightforward. This procedure happens gradually and requires analysing what topics are essential to present to students and establishing a suitable method. The primary tool used is the didactic book, which can improve efficiency in learning and be used as a base for teachers planning classes, although a 2018 analysis of Brazilian didactic books showed that very few books mention epigenetics in them [19].

Despite the bureaucracy, epigenetics can no longer be postponed from students’ curricula because it may improve students' interaction with genetic classes and can positively affect their lives and community. The following table presents some epigenetic themes, topics, and approaches to be taught based on [6],[19], focusing on curiosities,

subjects that may have a relation with their reality and the area of Health [4].

Tab. 1 - Themes, definitions and approaches suggested to be taught in the classroom.

Themes	Definitions and topics	Suitable Approaches
Concept of epigenetics	Layer of Information on top of the DNA	“Genome as hardware and epigenome as a software”
Influence of Environment on Phenotypes	The phenotype depends on the genome and the environment	Example of identical twins evolving differently
Epigenetics Mechanisms	DNA, methylation, modification of histones and micro RNAs, chromatin condensation	Discuss the effects of exercise, nutrition and cancer on those mechanisms
Epigenetics and inheritance	Cell differentiation and memory, meiotic/mitotic inheritance and evolution	Different types of body cells in individuals
Epigenetics and lifestyle	Pregnancy, lifestyle and social aspects	Students responsible on their own health and critical thought
Epigenetics and diseases	Cancer and mental disorders	Environmental Influence on Diseases
Epigenetics and forensics	Epigenetics method to determine the age of an individual	Epigenetic profiling in crime scenes

4. Discussion

Despite the fake news problems of having an essential discipline of biology being promoted intensely in social media, this leaves the teachers with a bonus: for those who have listened to epigenetics outside the school, it will bring much interest, thus, moving the debates at the classroom

dynamically. Jokes aside, there are other reasons why this fundamental new science should enter the secondary classrooms of Brazil. The present study aims to elucidate how epigenetics can be part of genetics classes in a way that will add more to the biology curriculum and make students more interested in Genetic classes. Considering the consensus among Epigenetics experts in the work from Gericke and Ewen (2023)[5], epigenetics should be inserted in the classrooms as part of genetics classes but could be mentioned in other disciplines too.

Based on the assumption that students are losing interest and finding difficulties in genetic classes because of the complexity of the topics and the distance from their reality [15],[16],[17], alternative methodologies should be implemented [24]). A suitable practice that is gaining attention from pedagogy scientists is Humanizing Pedagogy, María del Carmen Salazar, shows in Chapter 4, "A Humanizing Pedagogy: Reinventing the Principles and Practice of Education as a Journey Toward Liberation" (2013)[21], essential topics that must be considered when thinking an alternative pedagogy proposal, some highlighted were: the reality of the learner is crucial; critical consciousness is necessary for students and educators; students' sociocultural resources are valued and extended; content is meaningful and relevant to student's lives and students' prior knowledge is linked to new learning.

Improving the curriculum is another necessity of the educational system since it helps maintain school classes and news from the scientific universe together [18] and enhances critical thinking about their lives and community. However, it must be done with the challenges involving time, the number of themes teachers have to approach and the difficulties students experience with genetics. Especially when we talk about a subject that involves complex molecular processes; thus, according to Zudaire & Nepal (2021)[25], "is feasible to introduce epigenetics in secondary school curriculum: at lower levels, special attention should be paid to avoid inducing misconceptions that can work as conceptual barriers to complex genetic concepts exceeding linear determinism", they also suggest accessing technical details in non-obligatory context.

In this manner, the definitions of epigenetics should be first presented to students using a computation metaphor: "Our genome can be envisioned as the hardware of a computer. Our epigenome, the extra layer of information located on top of the DNA, can additionally be viewed as the software." [6], bring a simplified and intuitive notion of the theme, which is

necessary to complement posteriorly. An etymological explanation can be linked to the metaphor, as the prefix "Epi" means on top, and the epigenome is an extra layer of information put on the DNA, necessary to complement that epigenetics patterns do not affect the genome itself, only its regulation.

Genetic determinism disregards the environment from the impact on the cell or organism phenotype. However, epigenetics have come, since 1940, by the first definitions of Waddington, changing that concept. Developmental biology studies have shown that, despite all cells having the same genome, each cell develops differently because of its interactions with the external environment. In the same way, organisms like identical twins evolve differently because they establish singular interactions with the outer world [8], [5]. Hence, this leads to different cell and organism phenotypes, explaining the differentiation process [6].

Now, it is the moment to present to students the main epigenetics mechanisms through studies results that show how our habits influence these mechanisms' patterns. This class will be fundamental due to its potential to raise a responsibility in students' lifestyles or to exercise critical thought about a community's possibility of living in health conditions.

For DNA methylation, a good example is from Ronn et al. (2013)[12], "A Six Months Exercise Intervention Influences the Genome-wide DNA Methylation Pattern in Human Adipose Tissue". After reminding students of DNA methylation mechanisms, mention that this study described patterns of DNA methylation in 23 healthy men before (1) and after (2) practising six months of more intense exercise. What resulted in alteration in global DNA methylation in individuals, specific gene levels and the dynamic of adipose tissues. Also, after the period of exercise, the men in stages 1 and 2 have different VO₂ max, and this work showed that microRNAs are expressed differently in individuals with different maximal oxygen consumption. For histone modification, it is necessary to explain the role of histone in eu and heterochromatin again and how it affects gene expression. Then, present the example given by Chol Ha & Zamudio (2011)[26], "Environmental epigenetics in metal exposure", of how even brief exposure to metal arsenite is related to high levels of histone phosphorylation and alteration in the promoter histone modification, what leads to chromatin modification, thus, different gene expression.

A more complex definition of epigenetics is necessary for explaining epigenetics and inheritance. For this, the definition of Bird (2007)[7]

can be used, Epigenetics as an area that investigates meiotically and mitotically heritable and reversible changes in patterns of gene expression that do not affect the primary sequence of DNA [7]. For this class, the understanding of meiosis and mitosis should be settled or recapitulated since cells divide by mitosis all the time, and in this process, the daughter cells inherit epigenetic patterns repeating phenotypic arrangement. However, in meiosis, these epigenetic patterns would be sent to other generations. This part must be taught with caution since it is not sure that all organisms inherit meiotic changes in gene expression patterns. Especially in plants and fungi, in animals, a study on the mouse agouti locus has shown that epigenetic arrangements were passed through the next generation [7]. Also, unreliable affirmations on media and books where disseminated around this topic mostly, so students must understand well that although genes can have a “memory”, and things experienced by our grandparents like food, air and trauma can be passed through generations and affect us in the present, how this happens is still not well explained, which is part of the nature of science [7], [6].

Accordingly to Gericke and Ewen (2023)[6], lifestyle influences on epigenetic changes also deserve attention when taught due to ethical implications and uncertainties in the process. Although, the importance of giving critical individuals responsibility for their health is essential, and the teaching around this theme should focus on this fact. Also, it was shown in epidemiological studies that women's habits when pregnant, like diet, smoking, stress, gestational diabetes and drinking alcohol, can impact DNA methylation and modification of histones and chromatin, which can lead to posterior plasticities like autism spectrum disorder, congenital heart defects, allergies and cancer [27].

Although there is no evidence of epigenetics dysfunctional patterns causing any disease, it is widely mentioned in the aggressiveness of diseases[6],[9], [28] like cancer, syndromes involving chromosomal instabilities and mental retardation [29]. On the other hand, epigenetics mechanisms have been shown to have an anti-tumorising effect for some malignant cancer, so it is also a potential for cancer therapy. The last theme this study indicates to apply in class is a curiosity about the accuracy of epigenetics techniques to determine an individual's age, which can be even more precise than telomere length. This could be useful in profiling crime scenes for forensics science [6].

These and other subjects should be adopted to implement epigenetics in the classroom, but first,

teachers need to be more involved in the discussion. For this, Ewen (2022) [30] assembled a Review about Epigenetics for Biology Teachers by presenting a theoretical framework of epigenetics; in this way, the study will help teachers and other non-experts to construct appropriate curricula for education. However, It was shown by Quaresma et al. (2022)[19] that only three of six books researched in 2018 mentioned epigenetics in a simplified way, and two of them, it was inside chapters like Mendelian Genetics and Mechanism of Inheritance.

Thus implementing a didactic book, as a tool in addition to professional knowledge, concerning epigenetics profoundly and transparently is essential for the curriculum and has to be dispersed around schools in Brazil.

5. Conclusion

The present study aimed to suggest subjects around epigenetics to be implemented in the high school curriculum. Highlighting the importance of education as something that has to be updated as part of its nature, but also considering that education in Brazil needs many improvements and students already demand attention in genetic classes. So for the implementation of epigenetics in school is necessary to reach topics related to students' reality, curiosities and interests, using a humanizing pedagogy to conclude the teach-and-learn process in class effectively and to path through topics that exercise self-improvement in habits, critical thinking and social development.

Many themes and forms of approaching it that were suggested in this study are requested in crucial educational institutions and documents in Brazil, such as Nacional Curriculum Parameters (PCN), Nacional Common Curricular Basis (BNCC) and the Ministry of Education and Culture (MEC). Furthermore, Epigenetics is part of the Nacional Exam of High School (ENEM) and other universities' entrance exams, showing that this knowledge is already socially required. Thus, the necessity of epigenetics on an updated curriculum and assembling didactic books to complement epigenetics in school education can no longer be postponed.

6. References

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