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Title **Sickle cell anemia as a racialized disease: Design principles of a teaching sequence for education about ethnic racial relations**

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Abstract In this paper, we present the results of the first prototyping cycle of an Educational Design Research aiming at the validation of design principles of a Teaching Sequence (TS) on the racialization of sickle cell anemia and its relations with the history of scientific racism. The goal of the TS is to promote education about ethnic-racial relations, health education, and a balanced critical understanding of science in the context of a biology preservice teacher education course in Brazil. The three design principles investigated in this paper refer to the specific goal of promoting education about ethnic-racial relations in a

science teaching context: 1) Approaching the polysemy of the concept of human races; 2) Making a critical examination of sickle cell anemia racialization along history; 3) Addressing the risk of a new eugenics in the genetic counseling process. We tested the TS in 2018, in six meetings with students. In our analyses, we found evidence validating the three investigated design principles. After the formative evaluation of this prototype, we refined the principles and the TS to carry out a new prototyping cycle.

Keywords Educational Design Research
Ethnic-racial relations
Scientific racism
Sickle cell anemia racialization
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Sickle cell anemia as a racialized disease: Design principles of a teaching sequence for education about ethnic racial relations

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1.0 Introduction

In this paper, we report the results of a research that investigated design principles of an educational intervention to approach sickle cell anemia racialization and its relations with the history of scientific racism. The purpose was to promote education about ethnic-racial relations, health education, and a balanced critique of science, in the context of biology preservice teacher education in Brazil. In this work, we will focus specifically on the promotion of education about ethnic-racial relations in the intervention.

This study followed the Educational Design Research theoretical-methodological framework (Plomp, 2009). The educational intervention investigated was a Teaching Sequence (TS), which, according to Zabala (1998, p. 10), is "a set of ordered, structured and articulated activities for the realization of certain educational objectives, which have a principle and an end known to teachers and students alike".

Sickle cell anemia is the most frequent genetic disease resulting from a single mutation in Brazil (Cançado & Jesus, 2007). People with the disease can manifest different symptoms, the severity of which depends on many aspects, such as biological, social and economic conditions and access to health care assistance (Naoum, 2000). Despite its high prevalence in Brazil, sickle cell anemia is made invisible and stigmatized as a "black people disease" (Cavalcanti & Maio, 2011). This invisibility is an instance of a historical negligence of Brazil´s state with public health of black people (Mota et al., 2017).

In the school context, lack of knowledge about sickle cell anemia is frequent, even among teachers, who have a fundamental role in welcoming and teaching students affected by the disease (Santana et al., 2014). Depending on the severity of the illness, these students tend to miss classes more often than their peers and may have lower school performance, due to the symptoms of the disease and their frequent need for hospitalization. As a result, these students have more difficulties to access and stay in school, which poses a challenge to their education (Barros et al., 2012).

In addition to be prepared to welcome and support students with sickle cell anemia, the school should also provide a critical

understanding of the process of racialization of the disease, as a way to promote education against racism, especially in biology classes. After all, sickle cell anemia is a content addressed in biological education. This approach makes possible to link biology curricular contents, such as evolution and genetics, to education about ethnic-racial relations. Thus, it is essential that future biology teachers develop a critical and sensitive view of the disease along their education, such that they can properly deal with these issues in the classrooms.

1.1 The racial discourse on sickle cell anemia and its relations with the history of scientific racism

Throughout history, scientific discourses on the existence of racial hierarchies have contributed to justify the stigmatization, marginalization, and extermination of different human groups based on scientific racism (Sánchez-Arteaga & El-Hani, 2012).

Potential cases of scientific racism occur in certain discourses and practices of current biomedicine (Sánchez-Arteaga et al., 2015). Sickle cell anemia is an example, as it has been characterized as a disease of black people since its first description (Mota et al., 2017).

Sickle cell anemia was first described in the United States, in 1910, based on blood samples from a black patient of Caribbean origin. Since then, the disease has been racialized in many biomedical approaches (Beltrán-Castillo, 2018; Carmo et al., 2013; Cavalcanti & Maio, 2011; Mota et al., 2017; Tapper, 1999; Wailoo, 2006).

This racial characterization of the disease reinforced a widespread idea in the early 20th century that characterized black people as transmitters of diseases, resulting in discriminatory measures, such as compulsory diagnostic testing for African-Americans in the United States (Tapper, 1999; Wailoo, 2006). In the Brazilian context, biomedical works blamed miscegenation for causing a public health problem in the country linked to sickle cell anemia (Cavalcanti & Maio, 2011). Currently, racialization exposes people affected by this disease to different inequities. In Brazil, there are various consequences of this process, such as the delay in creating a public policy to assist people with sickle cell disease (Mota et al., 2017). The attendance at public health units is permeated by stigmas, which sometimes reflect institutional racism (Kalckmann et al., 2007). In addition, there is a risk of eugenic practices through inadequate genetic counseling (Diniz & Guedes, 2005; Silva et al, 2020).

This racial association, however, disregards biogeographical, evolutionary, historical, and political aspects related to the higher prevalence of the disease in black people, which have been known for some decades already. The mutations that gave rise to the HbS hemoglobin allele (called the S allele), associated with sickle cell anemia, occurred independently in the African continent, India, and

the Middle East (Templeton, 2013). This association also fails in considering evolutionary explanations for the maintenance of the S allele in malarial regions. People who have the S allele are more resistant to malaria due to various mechanisms resulting in lower levels of infection, especially in children (Mangano et al., 2015). Thus, heterozygous subjects (HbAS) have the protective effect of the S allele on malaria, with greater chances of surviving and maintaining the S allele in the population. Therefore, neither the origin of the S allele is restricted to Africa, nor there is anything intrinsic to black people related to the illness.

A historical analysis is needed to understand the higher prevalence of the disease in black populations in Brazil, as well as its social and political consequences. The S allele came to the country through the trafficking of enslaved people, brought by force from different regions of Africa from the 16th century onwards (Naoum, 2000). This explains why the disease is more prevalent in black people of African descent in Brazil, who historically have suffered from numerous additional health inequities (Mota et al., 2017). This understanding shifts the discourse about the disease from a biological approach, with racial connotations, to a political and social understanding (Caponi, 2020). This shift is particularly important in the educational context, where it allows building a critical discourse on the racialization of the disease.

In this work, we argue that teaching about sickle cell anemia racialization and its relations with the history of scientific racism should consider three fundamental ideas. The first one concerns the possibility of a historical approach to scientific racism, acting as a platform to address current cases of stigmatization and marginalization based on scientific discourses and practices (Sánchez-Arteaga et al., 2013). This approach can be fruitfully built from the perspective of Science, Technology and Society (STS) education, which contribute to point out the complex relationships between scientific and technological production and the social, cultural, political, economic, and moral values (Sánchez-Arteaga & El-Hani, 2012).

The second idea that underlies this work is that of discussing the different meanings attributed to the race concept throughout history, as a relevant topic for promoting education about ethnic-racial relations in the context of science teaching (Verrangia & Silva, 2010; Sepulveda et al., 2022).

The third idea is in line with the claim by Martins et al. (2018) that it is possible to connect theoretical perspectives in education – such as STS – with health education. According to these authors, this is particularly so from a socioecological approach to health that treats health and disease in a comprehensive way, including historical, social, political, and economic aspects, in addition to the biomedical ones.

An approach to sickle cell anemia from this perspective needs to focus on the stigmatizing and marginalizing potential that certain biomedical discourses carry in relation to the racialization of the disease, in order

to avoid the reproduction of stereotypes and prejudices in the classroom. This becomes especially important when we consider that high school biology textbooks in different countries contain outdated information about the disease that is potentially racist and stigmatizing (Beltrán-Castillo, 2018; Carmo et al., 2013).

2.0 Educational Design Research as a theoretical-methodological framework

Educational design research is carried out along linked phases: 1) Preliminary Research; 2) Prototyping Phase; 3) Evaluative Phase (Plomp, 2009). In this study, we report the results of the first prototyping cycle, involving the elaboration, testing, and formative evaluation of the first TS prototype. Therefore, this paper includes outcomes from the Preliminary Research and Prototyping phase.

2.1 Preliminary Research

In the preliminary research, we analyzed the educational problem based on a literature review, focused on the history of scientific racism, the polysemy of the concept of human races, and the debates regarding sickle cell anemia racialization throughout history.

The literature review dialogued with the previous experience and knowledge of the teacher who collaborated with this research applying the TS in the classroom. Moreover, the teacher provided information about the student class and the discipline in which the TS was applied, "School Knowledge Construction and Evolution Teaching", in the context of a biology preservice teacher education course at the State University of Feira de Santana, State of Bahia, Brazil. The TS was applied in June 2018. The class consisted of 22 students.

The preliminary research phase resulted in the development of a conceptual and theoretical framework for the study, including the creation of design principles and the adaptation of principles already existing in the literature. We elaborated these design principles following the formulation proposed by van den Akker (1999) contemplating a substantive aspect, a procedural aspect, and arguments supporting the design principle.

The six initial design principles elaborated are listed in Table 1[1]. Among these, we developed three principles within the scope of this research, which are related to polysemy of the concept of race (Principle 1), the racialization of sickle cell anemia (Principle 2), and genetic counseling (Principle 3). The other three design principles were adapted from Sánchez-Arteaga and El-Hani (2012) and have been validated by

[1]In this work, we present only the theoretical foundations, substantive aspects, and objectives of the design principles due to space limitations. See Meyer Nascimento et al. (2019) and Meyer (2020) for more details of the principles.

Fadigas (2015) in a previous study, carried out in a similar educational context.

Table 1

Initial TS design principles and related teaching expectations (elaborated by the authors)

Theoretical Foundations	Design principle	Teaching expectation
Munanga (2004); Sepulveda et al. (2022); Verrangia & Silva (2010); Wade (2017)	1 – Approaching the concept of race: its polysemy, and its relevance for the promotion of education about ethnic-racial relations in science teaching.	a) To enable students to articulate the meanings attributed to the race concept throughout history with racism and the construction of tense ethnic-racial relations in society.
Cavalcanti & Maio (2011); Mangano et al. (2015); Mota et al. (2017); Naoum (2000); Tapper (1999); Templeton (2013); Wailoo (2006)	2 – Critical examination of the racialized discourse on sickle cell anemia as an example of scientific racism and problematization of the higher prevalence of the disease in black populations.	a) To promote an analysis of the historical racialization of sickle cell anemia and its relationship with scientific racism. b) To examine evolutionary, biogeographical, and historical explanations for the higher prevalence of the disease in black populations.
Diniz & Guedes, (2005); Hansen et al. (2008)	3 – Approaching the risks of developing new eugenic practices through inadequate genetic counseling.	a) To guide students in analyzing the potential problems of genetic counseling aimed at people with sickle cell anemia and heterozygous subjects.
Sánchez-Arteaga & El-Hani (2012); Fadigas (2015); Martins et al. (2018)	4 – Use of a socioecological approach to health education that favors the empowerment of students to recognize potentially stigmatizing biomedical discourses in relation to sickle cell anemia.	a) To guide students in the analysis of different health approaches to sickle cell anemia. b) To favor the recognition of the socioecological approach as a way of understanding health in a comprehensive way.

Sánchez-Arteaga & El-Hani (2012); Fadigas (2015)	5 – Considering STS relations involved with the history of scientific racism.	a) To promote the analysis of the ideological, cultural, political, and social aspects that influenced scientific racism along history.
Sánchez-Arteaga & El-Hani (2012); Fadigas (2015)	6 – Employment of a balanced critical approach to science.	a) To stimulate students to engage in a balanced critique of science and its relationship with society.

2.2 Prototyping Phase: Construction and elaboration of the TS

In the prototyping phase, we elaborated the TS based on the design principles[2]. Table 2 shows the themes of the TS classes as well as the design principles mobilized in each class, which lasted for approximately 100 minutes.

Table 2
TS class theme and related design principles (elaborated by the authors)

Class theme	Design principles
1 – Brief overview of the social implications of Darwinist thought	5 and 6
2 – Concept of interracial competition and racial extinction in the human species, and whitening ideology	1, 5 and 6
3 – Polysemy of the race concept and its implications for the education about ethnic-racial relations in science teaching	1, 5 and 6
4 – Critical examination of sickle cell anemia racialization	1, 2, 3, 4, 5 and 6
5 – Genetic counseling: risk of a new eugenics?	3, 4 and 6

2.3 Prototyping Phase: Formative evaluation

For the formative evaluation, we analyzed whether the teaching expectations of the TS were achieved or not. The formative evaluation took place through the analysis of discursive interactions that emerged during the TS activities. For this, we video recorded the TS

[2] The complete didactic sequence is available at: https://sarahbaartman.pro.br/proposta-pedagogica-anemia-falciforme/

implementation in the classroom. We analyzed data from this prototype based on the selection of teaching episodes which constituted the unit of our analysis, amounting to a set of turns of speech, considered relevant in terms of the objectives of the study.

The teaching episodes indicated whether each of the teaching expectations (Table 1) related to the design principles were achieved during the activities. We focused on validating the three design principles developed in this study – Principles 1, 2 and 3 –, which are directly related to our objective of promoting the education about ethnic-racial relations.

Evidence of whether the teaching expectations were achieved or not was examined using Critical Discourse Analysis (CDA) (Fairclough, 2001). Thus, in the analysis of the teaching episodes, we sought to locate intertextual productions that evidenced the structuring of the discourse in terms of the teaching expectations related to each of the three investigated design principles, or, alternatively, the limitations in fulfilling these expectations.

3.0 Analysis of results: implications for practice and theory

3.1 Validation of Design Principle 1

At the end of the class on the polysemy of the concept of race (Class 3), to address the current social and biological concepts of race, the teacher discussed with the students the content of three banners that brought social statistics of racial profile in Brazil, showing the higher risk of violent death for black Brazilians. The clipping of this episode (Table 3) begun with a discussion of one of the banners that affirmed: "Science has already proved the non-existence of human races, but there is still a strange tendency for firearms to target young black men". It ended with considerations on the social implications of the concept in maintaining inequalities between blacks and whites in the country.

Table 3

Discursive interaction related to Design Principle 1 (elaborated by the authors)

1 – Teacher: What do we have on that banner over there? What do you think it happens with the concept of race when genetics says that there are no races, that race is inappropriate?
2 – Student A: I think that hierarchy still exists socially. I don't think so, I'm sure. Especially with those stats there.
3 – Student B: The concept of race was delegitimized by science... In science... However, in society racial issues, hierarchization, these things, continue to exist. Moreover, racism comes from the structure of colonization and so on and is still here today. In addition, that Law[3]... If we think about it... We don't talk much about

[3] The student refers to the Brazilian Law nº 11.645/2008 (available at:

these issues, for example, in the classroom. Is it discussed in the classroom? Nobody talks, for example, about the concept of race that served for this, this and that... Moreover, today it no longer exists for science.

4 – Student C: Another question, they brought blacks from Africa and enslaved them... Slavery ended, but they were in a condition of...

5 – Student B: ...Extremely vulnerable...

6 – Student C: ...Without land, without anything. There were a people who were left without support, without anything, and to this day, we suffer from this.

In the intertextual production of students in speech turns 2 and 3, there is the consideration that the hegemonic discourse of current genetics about the non-existence of human races, in biological terms, is not enough to extinguish human hierarchies and racism in society, as this would be a concept "rooted" in our society. Speech turns 3, 4, 5 and 6 are especially relevant in relation to the teaching expectations associated with Principle 3, because they explain the ideological use of the race concept along history as an instrument for colonial domination and slavery. The intertextual production in these turns also exposes how these processes influenced the tense ethnic-racial relations that last until today. They provide evidence that the teaching expectation linked to Principle 1 has been achieved.

In turn 3, student B notices that the historical debates on the concept of race in the classroom are configured as an opportunity to address the history and culture of Afro-Brazilian people as a content on scholar education but considers that these debates are absent from the classrooms. This reflection by the student converges with Verrangia and Silva (2010) who claim that education about ethnic-racial relations is rarely present in classrooms, and that approaching the history of the race concept is a possible way forward to promote the education about ethnic-racial relations in science teaching. In addition, this is a discourse of contestation of reality by the student. We consider student B's intertextual elaboration to be further positive evidence that the teaching expectation related to Principle 1 has been achieved.

3.2 Validation of Design Principle 2

This validation involved the two teaching expectations related to Principle 2 (Table 1). Initially, we will discuss the results related to

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https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2008/lei/l11645.htm), that made it mandatory to include the teaching of Afro-Brazilian and Indigenous history and culture in the official curriculum of Basic Education in the country.

teaching expectation “a”, followed by the evaluation of teaching expectation “b”.

This episode happened in class 5, while the students and the teacher were discussing the activity to evaluate the approach to sickle cell anemia in excerpts taken from high school biology textbooks (Table 4).

Table 4

Discursive interaction related to Design Principle 2, teaching expectation “a” (elaborated by the authors)

1 – Student A: I think it took a long time for there to be a concern about this disease because from the beginning it was seen as a disease of black people, so to speak. Therefore, I think there was no concern to try to provide a life quality for these people. In addition, we see it even today... Even at school, they always said that sickle cell anemia is a disease of black people, but they never said why. It's something that ends up being reproduced but people don't even know how to justify what they say. Why? Because it is a historical question. Moreover, this issue, by linking the disease to the black man and the black woman... The concern for the health of these people took a while.
2 – Teacher: What took time? A public policy to support, to assist...?
3 – Student A: Yes, to improve life quality, so that these people could have a longer life expectancy.
4 – Teacher: I think it's not very good for us to talk about black people's disease, because it leads to an attribute as if it were a quality of black people to have the disease, right?
5 – Student A: No, but I say... In society, we listen to this.
6 – Teacher: Yes. Therefore, what you have is that it is more common in black people.

In the intertextual production at speech turn 1, Student A denounces the State's delay in creating public policies for people with sickle cell anemia due to its racial connotation. Throughout her speeches, student A highlights the deprivation of rights to which people with sickle cell anemia were subjected due to the stigmatization and marginalization of the black population, as pointed out by Mota et al. (2017).

When the teacher, in speech turn 4, contests student A's speech in turn 1, about sickle cell anemia being a disease "of black people", the student clarifies that this is a widely disseminated discourse in society, even though people in Brazil do not know the reason for sickle cell anemia being more common among black people. In this intertextual production by student A, she also recognizes that this racialized

discourse resulted in health and social inequalities for people with sickle cell anemia. Finally, in speech turn 6, the teacher points out that the disease is more frequent in black populations, but it is not specific of these populations, changing the meaning of their relationship with sickle cell anemia. The intertextual productions of this episode offer evidence of the achievement of the teaching expectation "a" associated with Principle 2.

For examining teaching expectation "b" related to design Principle 2, we selected an episode during the analysis of the activity on the evolutionary relationship between the S allele and malaria, in class 4 (Table 5). On the occasion, the teacher projected a slide with a map that pointed out the overlapping of the geographic areas where the known haplotypes of the S allele were found and the areas of malaria occurrence, to discuss it with the whole class.

Table 5

Discursive interaction related to Design Principle 2, teaching expectation "b" (elaborated by the authors)

1 – Teacher: What does the third map indicate? Is it possible to say that sickle cell anemia is a disease of African origin? Why?
2 – Student A: Because there are several places where it occurred.
3 – Teacher: So, you have haplotypes, isn't that what you call it? You have haplotypes in regions of the globe other than Africa. These mutations have other origins of occurrence on the globe, not just in Africa. Moreover, what explains their frequency in the black population is not that it is a black disease. It is the fact that the allele is more frequent in regions that have malaria. As this region of Africa is one of the malarial regions... (The teacher points to the region on the map projected on the wall). What explains you having this higher frequency in blacks?
4 – Student B: The text says that it was through the historical moment... that it was from that moment on... Where the kidnapping, enslavement, brought Africans... That the introduction of the S allele in the Americas occurred.
5 – Teacher: So, if we are saying that it is a disease with a high incidence in Africa, because the allele is more frequent... Because of this advantage in relation to malaria... And if we had the black population in Brazil that originated in the process... The text called it kidnapping, some people will call it forced immigration in Brazil, why? To accentuate this from a political, social and historical point of view, which would be the enslavement process in Brazil.

In this episode, the teacher seeks to mobilize evolutionary and biogeographical explanations about the emergence of the S allele in different parts of the planet (speech turn 1). In a second moment, in

speech turn 3, the teacher questions the reason why the frequency of the S allele is higher among the black population in Brazil, seeking to raise historical explanations, in addition to evolutionary explanations. The two questions are directly related to the teaching expectation “b” associated with Principle 4. However, in both cases, the speeches mobilized by the students when answering the question (speech turns 2 and 4) did not satisfactorily meet the teaching expectation. In speech turn 2, the student refers to the occurrence of the allele, but not to its origin. In turn 3, the teacher restructures the student's speech to contemplate the origin of mutations in other parts of the planet, outside of Africa, referring to haplotypes. In speech turn 4, the student articulates a historical explanation for the entry of the S allele in the Americas; however, she does not consider an evolutionary dimension prior to the historical aspect. Then, in speech turn 5, the teacher restructures the explanation of the question seeking to articulate an aspect of the evolutionary explanation, superficially, with the historical aspect raised by the student. Thus, in both cases, the teacher needs to re-elaborate the students' speech to include fundamental explanations for achieving teaching expectation “b”. In this way, we found some limitation in achieving the teaching expectation “b”. A possible explanation for this limitation lies in the challenges encountered in the process of teaching and learning about evolution, including teaching about natural selection (Tidon & Lewontin, 2006).

3.3 Validation of Design Principle 3

The clipping of this episode (Table 6) took place during class 5, on genetic counseling, in which a true case about the process of genetic counseling provided by a blood donation center in Brazil was examined. This case worked as a springboard for discussing genetic counseling for people diagnosed with the sickle cell trait (heterozygotes HbAS) during pre-blood donation tests.

Table 6

Discursive interaction related to Design Principle 3 (elaborated by the authors)

1 - Teacher: Do you consider that some ethical principles that should guide genetic counseling discussed in the classroom were not observed in the case addressed in the text?
2 – Group: Privacy.
3 – Student A: And autonomy.
4 - Teacher: Autonomy, why? In what sense?
5 – Student B: Because he says that one of the objectives of counseling... This group counseling is related to reproduction. So, I felt that it induces you not to want to have children, because a child with sickle cell anemia will probably be born. When this discussion

comes from studies... from doctors, for example, this has a very big impact on how you will absorb this information.

6 – Teacher: So, the weight of the doctor's discourse... of biomedical sciences... of science...

7 – Student B: You can have a child, but it is advisable not to, because you can have a child with anemia, and he will die. So, it's very heavy information for you to assimilate all of a sudden, because you weren't expecting to receive this information.

8 – Researcher: In the analyzed case, it doesn't necessarily happen like that, does it? What we call a directive here, that is, saying what you should do... giving direction. But it can happen. So, this is a care you must take.

During the episode, in speech turns 2, 3 and 5, the students mobilize discussions held earlier in class about the ethical principles that should govern genetic counseling, especially about the ethical principles of privacy and autonomy. The students indicate that the genetic counseling did not observe these ethical principles in the case analyzed in the classroom, showing that they recognize the principles and operate with them in the case analysis.

In speech turns 5 and 7, student B raises the issue of the risk of directing reproductive behavior of the people undergoing genetic counseling and the misused prevention discourse in relation to their decision making. Discourses of this nature can assume a eugenic tone (Diniz & Guedes, 2005). Silva et al. (2020) report that a group of black women from the city of Salvador (state of Bahia, Brazil), when analyzing a municipal program of screening and genetic counseling for sickle cell disease, considered that the speeches conveyed racist and eugenic ideas, and were restrictive in relation to their reproductive rights.

In speech turn 8, the researcher makes the caveat that the directive speeches are not always explicit, as the one placed by student A in turn 7. This caveat is important because nowadays stigmatizing speeches that show eugenic potential can usually be subtle and apparently more palatable than past eugenic discourses (Hansen et al., 2008).

This episode provides evidence that the teaching expectation associated with Design Principle 3 has been fulfilled.

3.4 Formative evaluation of the Design Principles 1-3

In our formative evaluation of the first prototyping cycle, we obtained evidence for the fulfillment of the teaching expectations (TE) related to the following design principles:

TE_1 – To enable students to articulate the meanings attributed to the race concept throughout history with tense ethnic-racial relations in Brazilian society.

TE_{2a} – To promote an analysis of the racialized discourse about sickle cell anemia and its relationship with the history of scientific racism.

TE_3 – To guide students in the analysis of potential problems with genetic counseling aimed at people with sickle cell anemia and sickle cell trait.

We obtained, however, limited evidence for teaching expectation "b" associated with the Design Principle 4 (TE_{2b}) – to examine evolutionary, biogeographical, and historical explanations for the higher prevalence of the disease in black populations. In this case, although the students achieved a sufficient understanding of the historical explanations, the same was not true of the evolutionary and biogeographic ones.

Design Principles 1, 2 and 3 are closely related to our objective of promoting education about ethnic-racial relations. Thus, we consider that the TS achieved this objective, despite some limitations related to TE_{2b}.

4.0 Conclusion

In this article, we seek to answer the question about what would be design principles appropriate for a TS on the racialization of sickle cell anemia and its relationship with scientific racism, which could promote education about ethnic-racial relations in the context of biology preservice teacher education. Following the theoretical-methodological framework of the Educational Design Research, we consider that we validated three design principles:

P1 – Critical examination of the race concept, its polysemy, and the importance of discussing it to promote education about ethnic-racial relations and against racism in science teaching.

P2 – Critical examination of the racialization of sickle cell anemia as a historical example of scientific racism.

P3 – Addressing the risks of new eugenic practices aimed at people with sickle cell anemia or the sickle cell trait through inappropriate genetic counseling.

We also recommend considering to a fuller extent the evolutionary and biogeographical explanations about the maintenance of the S allele in different populations in revised prototypes of the TS.

In sum, the findings of the study indicate that the main objectives of the TS have been achieved and that this proposal can fulfill a relevant role as a way of promoting education on ethnic-racial relations, health education, and a balanced critical understanding of science based on the history of scientific racism. We also hope that our research can help to give greater visibility to the disease, oppose stigmatizing and

prejudiced discourses related to it, and include people with sickle cell anemia in the broader school and social context.

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