Thematic Dossier
THE TEACHING OF MATHEMATICS AND EXPERIMENTAL SCIENCES: REFLECTIONS ON THE PANDEMIC AND POST-PANDEMIC PERIOD
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STS EDUCATION IN THE TEACHING OF GEOMETRIC OPTICS FROM THE THEME VISION DEFECTS

EDUCACIÓN CTS EM LA ENSEÑANZA DE LA ÓPTICA GEMÉTRICA DESDE EL TEMA DE LOS DEFECTOS DE LA VISIÓN

EDUCAÇÃO CTS NO ENSINO DE ÓPTICA GEOMÉTRICA A PARTIR DO TEMA DEFEITOS DA VISÃO

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Abstract
This work consists of a report of experience referring to the Science, Technology and Society (STS) approach in the teaching of Physics carried out in professional high school classes, in a full-time agricultural school of the federal and public network, in the state of Maranhao (Brazil). It aimed to analyze the teaching of Physics in the programmatic content geometric optics/light phenomena and their consequences on human health through the subject defects of vision. The didactic and pedagogical strategy developed was the dynamic of Three Pedagogical Moments (3MP), with data structured according to content analysis. The research has a qualitative character, supported by quantitative elements, when necessary. In this way, the subject 'geometric optics/study of light' was developed, through the theme 'vision defects and their consequences on human health'. In the work with that theme, students carried out experiments with flat mirrors and simulation of visual impairment on a walk through the main school premises, as well as the work with the perception of pupil dilation, and the debate on those experiences. The analysis of the results suggests that, in fact, the teaching of optics through themes, in the context of the STS approach, enabled students to relate scientific knowledge and the problems experienced in everyday life by a visually impaired person, reflecting on real situations of the defects vision and the difficulties encountered by the visually impaired in everyday life, awakening them to citizenship.

Keywords: Citizenship; STS; Vision defects; Geometric optics; Three pedagogical moments.

Resumen
Este trabajo consiste en un informe de experiencia sobre el enfoque de Ciencia, Tecnología y Sociedad (CTS) en la enseñanza de la Física, realizado en clases de enseñanza media profesionalizada, en una escuela agrícola pública federal de tiempo completo en el estado brasileño de Maranhão. El objetivo fue analizar la enseñanza de la física en el plan de estudios de óptica geométrica/fenómenos luminosos y sus consecuencias para la salud humana a través del tema de los defectos de la visión. La estrategia didáctico-pedagógica desarrollada fue la

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dinámica de los Tres Momentos Pedagógicos (3MP), con los datos estructurados según el análisis de contenido. La investigación es de naturaleza cualitativa, con apoyo de elementos cuantitativos cuando es necesario. En la aplicación de los conocimientos, los alumnos realizaron experimentos con espejos planos y simularon la deficiencia visual en un paseo por las principales dependencias de la escuela, además de percibir la dilatación de los alumnos y debatir sus experiencias. El análisis de los resultados muestra que, de hecho, la enseñanza de la óptica a través de temas, en el contexto del enfoque CTS, permitió a los alumnos relacionar los problemas vividos en la vida cotidiana por las personas con deficiencia visual con el conocimiento científico, reflexionando sobre situaciones reales de defectos visuales y las dificultades encontradas por las personas con deficiencia visual en la vida cotidiana, despertándolos para ciudadanía.

Palabras clave: Ciudadanía; CTS; Defectos de visión; Óptica geométrica; Tres momentos pedagógicos.

Resumo
Este trabalho consiste em um relato de experiência referente à abordagem Ciência, Tecnologia e Sociedade (CTS), no ensino de Física, realizada em turmas do ensino médio profissionalizante, em uma escola agrícola da rede pública federal, de tempo integral, no estado do Maranhão. Teve como objetivo analisar o ensino do conteúdo óptica geométrica/estudo da luz e suas consequências na saúde humana, bem como observar as possibilidades dessa prática, no contexto da cidadania dos estudantes, por meio da temática 'defeitos da visão'. A estratégia didático-pedagógica desenvolvida foi a dinâmica dos Três Momentos Pedagógicos (3MP), com os dados estruturados de acordo com análise de conteúdo. A pesquisa tem um caráter de natureza qualitativa, com apoio de elementos quantitativos, quando necessário. Na aplicação do conhecimento, os estudantes realizaram experimentos com espelhos planos e simulação de deficiência visual em uma caminhada pelas principais dependências da escola, bem como percepção da dilatação da pupila e debate sobre as experiências vividas. A análise dos resultados evidencia que, de fato, o ensino de óptica através de temas, no contexto da abordagem CTS, possibilitou aos estudantes relacionar os problemas vivenciados no cotidiano por um deficiente visual com o conhecimento científico, refletindo a respeito de situações reais dos defeitos da visão e das dificuldades encontradas por deficientes visuais no cotidiano, despertando-os para cidadania.

Palavras-chave: Cidadania; CTS; Defeitos da visão; Óptica geométrica; Três momentos pedagógicos.

Introduction[2]

The norms governing Brazilian education, through the Law of Guidelines and Bases for Education (LDB), require that basic education aims to develop the student for citizenship with ethics and the development of critical thinking (BRASIL, 1996). This entails disseminating science education beyond purely scientific parameters, with the

[2] This work is part of a study partially presented at the VIII Ibero-American STS Seminar. Available in: https://revistapos.cruzeirodosul.edu.br/index.php/siacts/article/view/3607/2018.

purpose of providing students with values that help them understand science, technology, and their implications in decision-making within their daily context. In this perspective, the Curriculum Guidelines for High School (OCEM), in the part concerning Natural Sciences, Mathematics, and their Technologies, advocate that "one of the most important characteristics of the learning process in school is the reflective and self-critical attitude towards possible errors" (BRASIL, 2006, p. 45).

Thus, proposals from the National Common Curricular Base (BNCC) for high school, in the context of basic education, such as "knowing, appreciating, and taking care of oneself, one's body, and well-being, understanding oneself in human diversity, gaining self-respect and respecting others, drawing on the knowledge of Natural Sciences and their technologies" (BRASIL, 2017, p.324), align with the principles and purposes mentioned in the LDB and OCEM. In this regard, there is a need to involve civic practices, and science and physics education can significantly contribute in this field through education within the context of Science, Technology, and Society (CTS). In the teaching of science in Brazil, "[...] we are experiencing a rich moment for the advancement of contributions to scientific education for citizenship" (SANTOS, 2012, p. 59). Thus, the importance and necessity of contextualizing and involving civic practices in the field of education through the STS approach have been progressively disseminated (SOLBES; VILCHES, 2004).

Considering the above, this work constitutes an experience report on the teaching of physics, with the aim of analyzing the teaching of the content of geometric optics/light study and its consequences on human health. Additionally, it seeks to observe the possibilities of this practice within the context of student citizenship, focusing on the theme of 'vision defects,' within the framework of the STS approach and the dynamic of Three Pedagogical Moments. This was implemented in a federal agricultural school in the city of Codó, in the state of Maranhão.

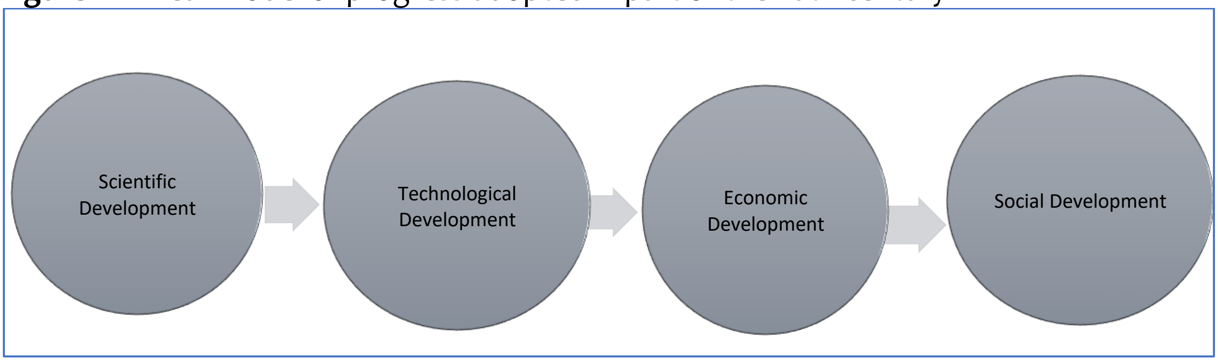
Approach of Science, Technology, and Society in Science Education

The increasing generation of science and technology on an ever-larger scale since the last century has caused enormous impacts on society. Specifically, starting from the Second World War, it became increasingly evident that both science and technology brought not only benefits but also harmful side effects. They were being used for the construction of weapons with detrimental effects on both humans and the environment, manifesting in various aspects such as environmental pollution and weapons of mass destruction.

Consequently, the Science, Technology, and Society (STS) Movement emerged in the mid-20th century as a reflection of the way traditional science and technology were generated (GARCIA et al., 1996). In this context, various social movements worldwide began to contest these developments, gaining significant influence and ultimately reshaping the way science is taught. Thus, the STS approach in science education is a consequence of the STS Movement. In this regard, science, from the STS perspective, means "teaching about natural phenomena in a way that embeds science within the social and technological environment of the student" (AIKENHEAD, 1994, p. 48).

Until then, the prevailing model of progress was based on the linear or traditional model, in which "scientific development (SD) generates technological development (TD), which, in turn, generates economic development (ED), determining social development (SD) – social well-being" (AULER, 2007, p. 8), as depicted in Figure 1.

Figure 1 - Linear model of progress adopted in part of the 20th century.

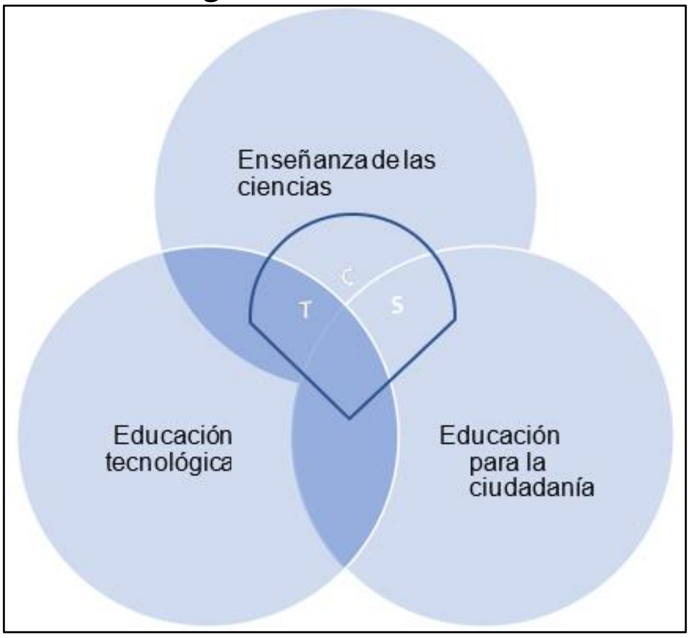


Source: Auler (2007), (adapted).

This linear developmental model did not yield the expected social development in practice and, consequently, faced many criticisms. In the field of education, official Brazilian documents emphasize training aimed at fostering citizenship, as recommended by the Law of Guidelines and Bases for Education (LDB) in its articles 2, 22, 35, and 36 (BRASIL, 1996). This purpose aligns with the assumptions of education in the STS (Science, Technology, and Society) field because "curricular proposals for science education from the perspective of science, technology, and society have as their main goal to prepare students for citizenship" (SANTOS; MORTIMER, 2001, p.95).

Studies in the STS context have been characterized by the interconnectedness of the relationships between "science education, technological education, and education for citizenship in the sense of participation in society" (SANTOS, 2012, p.51), as shown in Figure 2.

Figure 2 - STS Education.



Source: Santos (2012, p. 15)

In the current context, there are new guidelines for education through the National Common Curricular Base (BNCC), which incorporates STS (Science, Technology, and Society) education into their foundations. In this regard, high school, as part of the basic education cycle, includes the area of Natural Sciences and their Technologies, which stipulates that:

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> The social, historical, and cultural contextualization of science and technology is essential for understanding them as human and social enterprises. In the BNCC (National Common Curricular Base), it is also proposed to discuss the role of scientific and technological knowledge in social organization, environmental issues, human health, and cultural formation, in other words, to analyze the relationships between **science, technology, society, and the environment** (BRASIL, 2017, p. 549, emphasis added).

Therefore, in this work, we will consider the STS (Science, Technology, and Society) approach, which, in line with education for citizenship, advocates that "educating for citizenship is preparing the individual to participate in a democratic society through the guarantee of their rights and commitment to their duties" (SANTOS; SCHNETZLER, 2010, p.30).

The Pedagogical Practices of the Three Pedagogical Moments (3MP)

Pedagogical practices through the Three Pedagogical Moments (3MP) are based on the conception of Paulo Freire (1975) through generative themes and are adapted for systematic knowledge or formal education for teaching science. This approach is found in works such as "Física" by Delizoicov and Angotti (1990) and later "Metodologia do ensino de ciências" by Delizoicov and Angotti (2001). The 3MP consists of three distinct moments, namely:

i. Initial Problematic Situation: In this phase, themes or facts related to the content to be studied are presented, which students are already familiar with. During this teaching moment, students are encouraged to express their understanding of the situation. Thus, the initial problematic situation is characterized by students' comprehension and assimilation of the theme.

ii. Organization of Knowledge: In this phase, students need to study and systematize physics knowledge under the guidance of a teacher. At this point, it is essential to deepen definitions, concepts, laws, and possible applications of scientific knowledge to solve the problems mentioned in the introductory phase.

iii. Application of Knowledge: In the final moment, students attempt to analyze and interpret the initial study problems scientifically, as well as other situations not directly related to the initial motivation. It is evaluated whether the student has acquired the ability to justify and critically participate in the questions initially raised (MUNCHEN, 2010; DELIZOICOV and ANGOTTI, 2001).

Therefore, studying through themes within the context of the STS (Science, Technology, and Society) approach and utilizing the Three Pedagogical Moments (3MP) involves integrating science content into students' daily lives with the purpose of contributing to dialogicity, problematization, and a humanistic conception of education (SANTOS, 2008; DAGNINO, 2008).

Methodological Procedures

This research was conducted at an institution that originated from the federal agricultural school model, which has since been incorporated into the current federal institutes. It is located in the city of Codó, in the eastern part of the state of Maranhão, approximately 300 km from the capital, São Luís, on the edge of the Legal Amazon (Fig. 3). The institution covers an area of about 210 hectares, with building structures consisting of lightweight materials and open elements, integrating the constructed space with the natural environment. The natural environment is characterized by a forest typical of the interface between the coconut palm groves and the Amazonian environment. Among the different spaces in the environment, there are administrative and pedagogical modules, classrooms, laboratories, and a large area dedicated to typical agricultural and agro-industrial activities.

Figure 3 - Map of Brazil showing the Legal Amazon and the location of the city of Codó, Maranhão.

Source: Brazilian Institute of Geography and Statistics (IBGE). Colors and illustrative dimensions adapted by Nuno Santa Rosa.

To achieve the objective of this research, a qualitative approach supported by quantitative elements was chosen. This is an exploratory type of research aimed at providing an overall view of a phenomenon (cf. GIL, 1999).

This investigation took place between November 2018 and January 2019 in the discipline of Physics II: Geometrical Optics, involving four classes of the second year of vocational high school (Table 1) at a federal public institution in the city of Codó, in the state of Maranhão.

Table 1 - Second-year classes of vocational high school.

Classes - Technical Vocational Courses	Number of Students
Agriculture	37
Agroindustry	38
Environment	39
Information Technology	35

Source: Research data (2019).

In this context, in the first class, students were presented with a motivating text titled "A VISIT TO THE OPHTHALMOLOGIST: a theme for the teaching of Physics" by Sales (2008). During this time, questions and doubts of the students were raised. The work explores the theme of a visit to the ophthalmologist in a research paper for a graduation thesis, delving into physical concepts such as the study of vision phenomena, reflection and refraction of light, plane and spherical mirrors, lenses, and vision defects. The text narrates the story of a father who is reluctant to visit the ophthalmologist to address his vision problems but, with the help of his wife, decides to consult the doctor and takes along his 11-year-old son to the clinic, an intelligent and curious boy who wants to understand from the doctor the meaning of those procedures and instruments (SALES, 2008).

The Didactic Sequence was constructed over 7 sessions, each lasting 90 minutes (Table 2), held once a week. The teaching materials included a whiteboard, marker, multimedia projector, and personal computer/notebook (owned by the teacher), as well as photocopied texts and the textbook from the National Textbook Program (PNLD), which was used by the students.

Table 2 - Didactic Sequence of the Three Pedagogical Moments applied to the content 'Geometric Optics' in vocational high school classes.

Three Pedagogical Moments	Classes	Activities
Problematic Situation	1 class	The theme was introduced by reading the text 'A visit to the ophthalmologist', followed by a survey in which students presented questions, curiosities, and comments about Geometric Optics. This allowed for a brief overview of the students' perception of the topic.
Organization of Knowledge (4 classes)	1 class	Exploring the physical concepts of Geometric Optics: Rays and beams of light; Transparent, translucent, and opaque media; Optical phenomena; Color of an object due to reflection; Principles of light propagation, shadow, penumbra, pinhole camera (basic principle of a camera), and eclipses.
	1 class	Reflection in flat mirrors and the construction of images, some everyday applications.
	1 class	Reflection in spherical mirrors, geometric construction of images, some technological applications, and societal implications. Practical work on image formation in flat mirrors.
	1 class	Refraction of light. Vision defects and optical instruments. Experiments with light refraction in a glass of water. Technological applications and social implications.
Application of Knowledge (2 classes)	1 class	Practical lesson: i. Observing pupil dilation. ii. Simulation of a visually impaired person and discussion.
	1 class	Conclusion of the content with assessment.

3MP = Three Pedagogical Moments (2019).

Data analysis was carried out considering the perspective of content analysis by Bardin (2011).

Results and Discussions

The questioning and dialogical relationship of the STS (Science, Technology, and Society) approach and the 3MP (Three Pedagogical Moments) highlight their strong interconnection, facilitating an important didactic-methodological process. As an initial provocation, students were encouraged to speak up about various problems related to the topic of Geometric Optics. In this way, during the first class, a total of 70 questions and curiosities about the text were raised. However, for the sake of space and importance, we will highlight five of them (Table 3) below:

Table 3 - Main questions asked by students about the content of geometric optics.

	Questions
I	What is the difference between reflection and refraction?
II	What is the difference between a flat mirror and a spherical mirror?
III	What causes myopia, hyperopia, astigmatism, and what are the appropriate lenses to correct these defects?
IV	What is the Snellen test?
V	Are there other vision defects besides those mentioned in the text?

Source: Research data (2019).

Subsequently, in the second phase, the concepts, laws, and their technical applications were explored, along with the topic's relevance to everyday life. In this context, students learned about the laws of flat and spherical mirrors, as well as some vision defects. In Figure 4, students conduct experiments with image formation in flat mirrors to verify the concepts and laws that govern these mirrors. This experiment involves placing a flat mirror/glass on a flat surface, then positioning a lit candle (object) at a certain distance in front of the mirror. Behind the mirror, they place an unlit candle with different characteristics in size, and then another candle with the same size as the object and at the same distance, aligned perpendicularly to the mirror. The impression is that the unlit candle with the same size as the object is lit, indicating that this point is the image of the candle placed in front of the mirror. This experiment practically demonstrates to the students the principles of optics in a flat mirror: the image and the object are equidistant from the mirror, have the same size, and have opposite natures. In other words, for a real object, the image is virtual and vice versa, and they are enantiomorphic figures (opposite forms). Generally, this experiment leaves the students enchanted and excited to recognize the scientific laws in their everyday life situations.

Figure 4 - Classroom experiment demonstrating image formation in flat mirrors.

Source: The author.

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The application of knowledge is divided into two stages. First, an assessment of the content covered in this process was conducted: it was checked whether various questions and doubts raised in the initial phase had been understood and whether students had appropriated this knowledge. Thus, in Graph 1, the results of the questions in Table 3 are presented in the form of a multiple-choice test (closed questions Q1, Q2, Q3, Q4, and Q5), in a universe of 86 assessments. In summary:

Q1: It is related to the optical phenomena of reflection and refraction: students should differentiate these phenomena and scientifically understand what they mean.

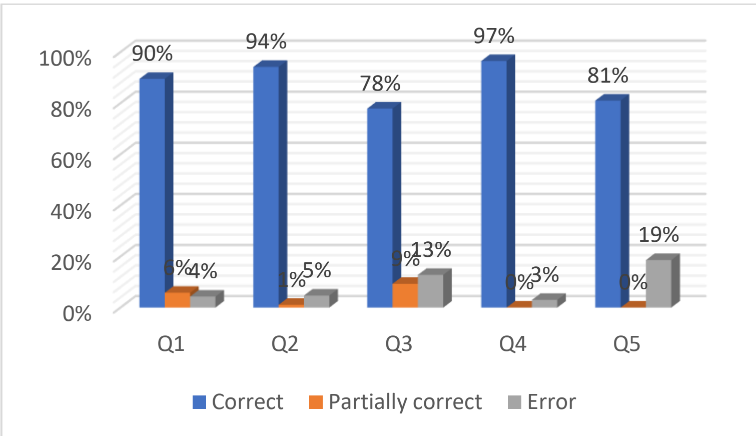
Q2: It deals with flat and spherical mirrors: students should differentiate between them.

Q3: It concerns some vision defects: myopia, hyperopia, and astigmatism, as contained in the text studied during the initial problematization.

Q4: It relates to the Snellen[3] test, used by ophthalmologists in their offices to assess patients' visual acuity.

Q5: It addresses other vision defects not covered in the text discussed in class that aroused the students' curiosity. These include presbyopia, strabismus, color blindness, and cataracts.

Graph 1 - Results of tests on content related to geometric optics in vocational high school classes.



Source: Research Data

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[3] Test in which the patient is placed at a certain distance from an optometric chart/table with standardized letters. The method was developed by the Dutch physician Herman Snellen with the aim of measuring the patient's visual acuity. The test is performed one eye at a time (ZAPPAROLI; KLEIN; MOREIRA, 2009).

When analyzing the students' responses to questions Q1, Q2, Q3, Q4, and Q5 aimed at assessing the teaching-learning process of questions I, II, III, IV, and V (Table 3), it is observed that most students responded favorably to understanding the questions posed at the beginning of the process. This highlights the contribution of the 3MP pedagogical process and the CTS approach to the development of science education.

The final assessment also included an 'open' question in which students provided a brief account of the content of optics studied in the classroom. In this regard, we obtained some responses, as mentioned by students E1, E2, and E3, presented below:

> Myopia, for example, is characterized by the fact that the image forms before the retina, requiring the use of a divergent lens. Hypermetropia is what happens when the image forms after the retina, the opposite of what occurs in myopia. In this case, convergent lenses are used (E1).
>
> The reflection of light is the phenomenon that occurs when light hits a surface and returns to its original medium. Refraction is when light passes from one medium to another (E2).
>
> In the classroom, the content on optics was for us to understand what flat and spherical mirrors are. So, flat mirrors are those where the object and the image are at the same distance from the mirror, and the produced image always has the same size as the object. In the case of spherical mirrors, the produced image is not the same as the object (E3).

The 'open' responses align with those provided in a 'closed' format, indicating that students understood the scientific aspect while also resolving some of the questions and issues raised in the initial discussion, encompassing the "Application of scientific knowledge, as indicated in the third stage of the 3MP (DELIZOICOV; ANGOTTI, 2001).

In the second stage of applying knowledge, two practical activities were conducted in pairs. In the first practical activity, the student examined their classmate's pupil in two situations: in low light and in a fully illuminated environment, with the aim of observing the influence of light on pupil size (Figure 5). In this context, there was a consensus among participants: when exposed to light, the pupil contracts compared to when it is shielded from light, thus protecting the eye from the harmful effects of ultraviolet rays.

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Figure 5 - Verification of the influence of light on pupil size.

Source: Author

Generally, the content of optics in textbooks concludes with vision defects. In this regard, in the second and final practice of applying knowledge, a simulated activity was carried out: students became visually impaired (completely blind) as part of an exercise to experience a portion of social inclusion as visually impaired individuals. Thus, students were paired up, with one of them being completely blind, wearing a blindfold, and the other being their guide. A walk was conducted through the school premises (Figure 6), and upon returning from the walk, the pairs switched roles between being blind and being the guide.

Figure 6 - Student experiencing being visually impaired.

Source: Author

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During the journey, three different situations were experienced. Thus, a route of approximately 300 meters was covered, from the classroom to the school's soccer field. In the first part, the guide colleague verbally directed the "visually impaired" student without physical contact (from the classroom to the courtyard/canteen area). In the second part (from the courtyard to the auditorium corridor), the guide colleague held the arm of the "visually impaired" student and guided them. In the third part of the journey (from the corridor to the soccer field), the "visually impaired" student held onto the arm or shoulder of the guide colleague, and they walked together. Subsequently, the process was repeated on the way back, with a role reversal in the experience: now the guide colleague became the "visually impaired" student, and vice versa.

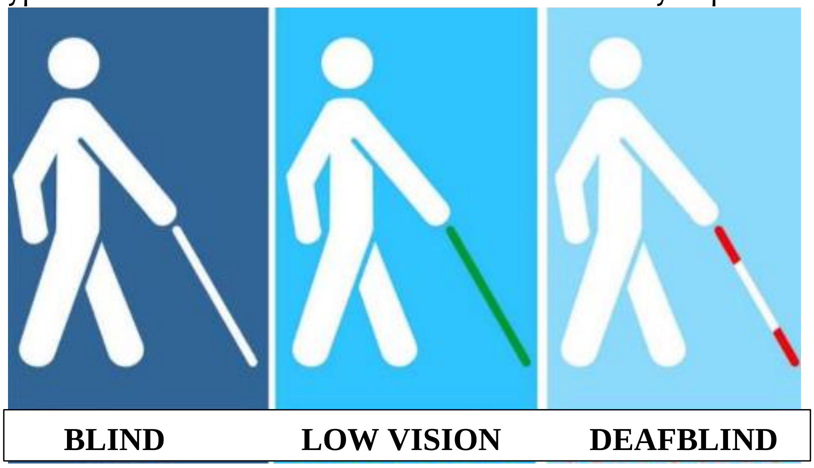
After this experience in the final stage of knowledge application, we returned to the classroom for a brief discussion. Some students argued that the school lacks the infrastructure to accommodate visually impaired individuals, although a few actions have been taken, such as the use of tiles indicating the path that visually impaired individuals should follow. However, in most areas, these indicators are not present. Figure 7 shows the increasing use of tiles to facilitate the movement of visually impaired individuals within the institution, aiming to comply with regulations. This was mainly due to a heightened awareness among students during physics classes, particularly in the context of geometric optics.

Figure 7 - Application of tiles to facilitate the mobility of visually impaired individuals.

Source: Author

When asked which of the three options for guiding a completely blind person was more suitable, most responses (60%) favored the situation where the visually impaired person holds onto the arm or shoulder of the guide. After this discussion, a braille specialist was invited to provide guidance on how to assist a visually impaired individual. The specialist indicated that the 3rd situation, where the visually impaired person holds onto the guide's shoulder or arm, is the appropriate choice. The specialist also explained that a visually impaired (blind) person usually uses a white cane, while someone with low vision uses a green cane. In the case of a person who is both visually and hearing impaired, the cane is red and white striped (Figure 8).

Figure 8 - Types of canes based on the condition of a visually impaired individual[4].



Source: São Paulo City Hall.

The specialist also emphasized that one should never make tasteless jokes when encountering a visually impaired person, as it can damage their self-esteem. He mentioned that visually impaired individuals often accept help, although some may not react positively to such situations due to not fully accepting their limitations or having experienced unpleasant encounters with strangers who took advantage of the situation, for example, by leading them in a different direction from the one they had requested assistance for.

[4] Informational material from the City of São Paulo aimed at educating the public on the use of canes by people with visual and auditory impairments. Retrieved from: https://pt-br.facebook.com/PrefSP/posts/1032424250289345/. Accessed on January 25, 2022.

In this regard, some students spontaneously expressed that when asked to guide a visually impaired person, they used to take them by the arm and lead them. However, they stated that they would now know how to do it properly. Therefore, the application of the 3MP dynamics through debate aligns with the principles of the STS approach afforded by Santos and Mortimer (2001), in which they affirm that for the development of decision-making skills, it is essential for students to discuss real-life problems. Thus, the STS (Science, Technology, and Society) approach should lead to "education for responsible social action." (SANTOS; MORTIMER, 2001, p. 102).

Final Remarks

This pedagogical practice structured the teaching of physics through dynamic actions of Three Pedagogical Moments (3MP) and thematic questions within a Science, Technology, and Society (STS) approach, creating an affinity between the curriculum and the students' everyday context.

The topic of the lesson, "a visit to the ophthalmologist," which addresses male resistance to seeking medical care, provided an extensive study of geometrical optics. This study brought with it the scientific significance of studying light and its social consequences in everyday life.

The teaching of geometrical optics was thus documented through problematization, where it was possible to verify arguments and records of considerations and questions initially, as well as acquire scientific knowledge. After the simulated experience of a person with visual impairment, who is part of a minority not always fully included in society, students were encouraged to reflect on civic actions within their school and city.

From this perspective, it was possible to observe the transformative power of science education through the pedagogical processes of Three Pedagogical Moments (3MP) and the interrelationship with the STS approach. In this way, students expressed their understanding of vision impairments, stating that there was someone with a visual impairment in their home or neighborhood. The main impairments they identified were cataracts, presbyopia (age-related farsightedness), and myopia (nearsightedness). They also affirmed that they would change their habits regarding social interactions with visually impaired individuals and their awareness of eye protection in relation to light exposure, demonstrating a greater sense of citizenship.

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