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Perceptions of Undergraduate Students in Biological Sciences on the Relationships between Science, Technology, and Society: Contributions to Environmental Education and STS Education in the Training of Future Teachers

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Percepção dos licenciandos em Ciências Biológicas sobre as relações entre Ciência, Tecnologia e Sociedade: subsídios à Educação Ambiental e à Educação CTS na formação de futuros professores

RESUMO

Neste artigo são apresentadas as percepções dos licenciandos do quarto ano do curso de Ciências Biológicas, de uma universidade pública, do estado de Mato Grosso do Sul, sobre as relações Ciência, Tecnologia e Sociedade (CTS). Os resultados foram obtidos por meio da aplicação de um questionário online a 12 licenciandos, durante o primeiro semestre de 2022, sendo posteriormente categorizados e codificados por meio das técnicas da Análise Conteúdo. A partir da análise, concluiu-se que os licenciandos reconhecem a influência de fatores ambientais, sociais, históricos, políticos e econômicos inerentes à epistemologia da Ciência e da Tecnologia, porém, devido à complexidade da própria natureza dessas interações, surgiram dúvidas e concepções errôneas ou incompletas que precisam ser superadas. Neste contexto, reitera-se o papel da Educação CTS e da Educação Ambiental, como estratégias educativas essenciais na busca pela superação de visões distorcidas sobre a natureza da Ciência e da Tecnologia, bem como na promoção dos processos de participação crítica nas tomadas de decisões individuais ou coletivas relacionadas à aplicação da CT no que tange à sustentabilidade socioambiental, considerando, sobretudo, as necessidades adaptativas e mitigadoras frente à emergência climática em curso.

PALAVRAS-CHAVE: Determinismo Científico e Tecnológico. Crise Ambiental. Definição CTS.

Perceptions of Undergraduate Students in Biological Sciences on the Relationships between Science, Technology, and Society: Contributions to Environmental Education and STS Education in the Training of Future Teachers

ABSTRACT

This article examines the perceptions of fourth-year undergraduates enrolled in the Biological Sciences program at a public university in Mato Grosso do Sul, Brazil, concerning the relationships between Science, Technology, and Society (STS). Data were gathered through an online survey administered to 12 students in the first semester of 2022, which were subsequently categorized and analyzed using content analysis techniques. The findings reveal that students acknowledge the role of environmental, social, historical, political, and economic factors in shaping the epistemology of Science and Technology. Nonetheless, the complexity of these interactions has led to the emergence of doubts, misconceptions, or partial understandings that need to be addressed. In this context, the role of STS Education and Environmental Education is emphasized as crucial educational strategies aimed at correcting misconceived perceptions about the nature of Science and Technology. Additionally, these educational approaches seek to foster critical engagement in both individual and collective decision-making processes relevant to the application of Science and Technology, particularly with regard to socio-environmental sustainability and in response to the challenges posed by the current climate emergency.

KEYWORDS: Scientific and Technological Determinism. Environmental Crisis. STS Definition.

Percepción de los estudiantes de licenciatura en Ciencias Biológicas sobre las relaciones entre Ciencia, Tecnología y Sociedad: aportes a la Educación Ambiental y a la Educación CTS en la formación de futuros profesores

RESUMEN

En este artículo se presentan las percepciones de los estudiantes de cuarto año de la licenciatura en Ciencias Biológicas, de una universidad pública del estado de Mato Grosso do Sul, sobre las relaciones entre Ciencia, Tecnología y Sociedad (CTS). Los resultados se obtuvieron mediante la aplicación de un cuestionario en línea a 12 estudiantes durante el primer semestre de 2022, categorizados y codificados posteriormente mediante técnicas de Análisis de Contenido. A partir del análisis, se concluyó que los estudiantes reconocen la influencia de factores ambientales, sociales, históricos, políticos y económicos inherentes a la epistemología de la Ciencia y la Tecnología. Sin embargo, debido a la complejidad de la naturaleza de estas interacciones, surgieron dudas y concepciones erróneas o incompletas que necesitan ser superadas. En este contexto, se reitera el papel de la Educación CTS y la Educación Ambiental como estrategias educativas esenciales para superar visiones distorsionadas sobre la naturaleza de la Ciencia y la Tecnología, así como para promover procesos de participación crítica en la toma de decisiones individuales o colectivas relacionadas con la aplicación de la CT en lo que respecta a la sostenibilidad socioambiental, considerando, especialmente, las necesidades adaptativas y mitigadoras frente a la emergencia climática actual.

PALABRAS CLAVE: Determinismo Científico y Tecnológico. Crisis Ambiental. Definición CTS.

1 INTRODUCTION

Since ancient times, humans have modified nature for survival, convenience, and to satisfy their desires, thereby highlighting the constant interactions between science, technology, society, and the environment (Bazzo, Pereira, & Bazzo, 2016). Yet, the prevailing system, focused on economic and productive development that favors possession over essence, has precipitated severe destructive impacts on the environment, leading to a dual crisis of civilization and environment (Vasconcelos & Freitas, 2012).

This ongoing civilizational and environmental crisis intensified during the latter half of the 20th century, a consequence of rampant natural resource exploitation, unchecked consumerism, and the consolidation of capitalism. These drivers significantly worsened issues such as the proliferation of solid waste, marine oil spills, deforestation, soil degradation, river pollution, flooding, poverty, and social exclusion (Freitas & Marques, 2019).

An additional critical factor is the escalating global concentrations of greenhouse gases (GHGs), such as carbon dioxide and methane, detected in air samples trapped in polar ice since the late 18th century. Martini and Ribeiro (2011) note that the intensification of these emissions is attributable to human activities impacting the environment, resulting in climatic changes that markedly deviate from the natural patterns observed over many millennia. Consequently, numerous scientists have adopted the term "Anthropocene" to describe the current epoch dominated by human influence, which has significantly intensified the Holocene—the warm period spanning the last ten thousand years.

The most recent reports by the United Nations Intergovernmental Panel on Climate Change (IPCC) on anthropogenic global warming reveal that carbon emissions from 2010-2019 were the most significant and severe recorded, pushing global warming towards an increase of more than double the 1.5 degrees Celsius threshold above pre-industrial levels. This threshold, established at the Paris Agreement in 2015, is considered critical to averting the most disastrous impacts of climate change. Despite these disturbing findings, the IPCC's 2023 report suggests that reversing this trend by 2030 is feasible through collaborative international efforts to reduce and eliminate both carbon and methane emissions. Nevertheless, the IPCC cautions that the current global response is inadequate to sufficiently counteract the ramifications of greenhouse gas (GHG) emissions, which are visibly altering climates across various regions of the globe.

Furthermore, Freitas and Marques (2019) assert that an environmental crisis is not merely the result of natural environmental changes but fundamentally arises from unrestricted human activities impacting natural systems. This situation is exacerbated by the perception of Science and Technology as catalysts for progress and development, often disregarding their social, ethical, environmental, cultural, and political ramifications. In light of this, it becomes imperative to reevaluate the prevailing model of economic and social development, which is often portrayed as neutral despite being deeply influenced by scientific and technological advancements.

The promotion of humanity's economic growth in a sustainable manner, ensuring that contemporary societal needs are met without compromising the environment or the welfare of future generations, thus averting catastrophic environmental changes, is explicitly articulated in the eighth Sustainable Development Goal (SDG-8), as set forth in the 2030 Agenda. Achieving this objective requires the adoption of individual, collective, and public policy measures that are informed by a comprehensive understanding of Sustainable Development (SD), extending beyond mere economic growth.

According to Vasconcellos (2008) and Melo (2010), the concept of Sustainable Development (SD) encompasses the preservation of nature, the atmosphere, soils, and water resources, as well as consideration of the social dimension which includes wealth distribution, social exclusion, and the universal right to citizenship and social justice. These authors emphasize that economic growth often occurs alongside extreme poverty, and that sustainable resource management can contribute to social equity.

In this context, recognizing the consequences of the current environmental crisis and the necessity to transcend the conservative approach in basic education, the urgency for implementing Environmental Education under a critical framework becomes evident (Rocha, Santos, & Pitanga, 2019). Critical Environmental Education requires students to explore the "historical, scientific, technological, and axiological" elements inherent to the human-nature relationship. The goal is for them to "adopt collective attitudes in their daily activities" to mitigate the environmental impacts of consumerism (Rocha, Santos, & Pitanga, 2019, p. 274).

To this end, Freitas and Marques (2019) advocate for an Environmental Education that integrates the theoretical foundations of the Science, Technology, and Society (STS) field. This approach involves a critical examination of content and pedagogical themes across a broad spectrum, establishing a "strong reference in problematizing STS relations and the environmental crisis" (p. 278). These authors contend that in the classroom, integrating STS relations with environmental issues can address the shortcomings in the application of STS concepts to the socio-environmental domain. This integration challenges the technological solutions to environmental issues, encouraging citizens to make informed decisions about the consumer products they choose.

There is a consensus among numerous scholars in the field of Science Education that both in Basic and Higher Education there is a need for pedagogical proposals that address the theoretical-methodological deficiencies in Environmental Education, as well as its often reductionist, fragmented, and individualistic approaches that fail to foster the development of attitudes conducive to sustainability (Amaral, Miguel, Lima, & Cutchma, 2018; Rocha, Santos, & Pitanga, 2019). However, this raises several questions: *What are the perceptions of Biological Sciences undergraduates regarding STS relationships? Has the education they received enabled them to form such relationships and comprehend the necessity of implementing Environmental Education initiatives at individual, collective, and public policy levels?*

To address these questions, the present study aimed to explore the perceptions of fourth-year undergraduates in Biological Sciences at a public university situated in the southern part of the Mato Grosso do Sul state regarding their understanding of Science, Technology, and Society (STS) relationships.

2 METHODOLOGY

This research was conducted with 12 (twelve) fourth-year undergraduate students in Biological Sciences at a public university in the state of Mato Grosso do Sul, during the first semester of 2022. It forms part of a broader investigation into the integration of Science, Technology, and Society relations within the curriculum of Biological Sciences courses.

This study is characterized as a qualitative, exploratory, and documentary research, utilizing a questionnaire as its primary data collection tool. The questionnaire comprised both closed structured questions, offering multiple choices, and open questions, which allowed undergraduates to use specific terms regarding the STS relationships. The inclusion of open questions was intended to address the limitations inherent in structured questionnaires, as noted by Flick (2013) and Minayo (2009), thereby facilitating more detailed responses suitable for in-depth analysis and reflection on the subject.

The administered questionnaire, comprised of thirty-one questions, explored aspects related to the social and academic profiles and perceptions of undergraduates concerning STS education within the Biological Sciences curriculum they were enrolled in during 2022. However, for the purposes of this analysis and to achieve the study's objectives, only responses related to specific areas were selected: i) the designation of STS, ii) the implications of Science and Technology in society, iii) the influence of society on the scientific and technological agenda and production, and iv) uncertainties concerning the STS relations.

The questionnaire was administered using an online survey platform. Flick (2013) affirms that in this type of research, surveys can be conducted via email or the internet. When administered via email, the pre-selected recipients are sent a questionnaire which they must complete and return as an email attachment. In this study, however, we opted for an internet survey, developing the questionnaire using the Google Forms tool. This approach offers greater flexibility in question formulation and enhances the efficiency of data collection, organization, and analysis (Flick, 2013).

Upon acquiring the data, the analysis was conducted using the Content Analysis techniques described by Bardin (2016). This method is designed to transform "raw" information into structured research results through procedures that systematize, categorize, and facilitate the analysis of the phenomena under investigation (Bardin, 2016). During this analytical process, elements pertaining to the Science, Technology, and Society relations were consolidated into a thematic category. Subsequently, the units of records were identified and organized through the coding process.

In this manner, the selected and coded units of records in the research corpus, specifically the STS elements, were identified by two initial letters corresponding to the type of document analyzed: for instance, QU (questionnaire for undergraduate). This was followed by two sets of numbers: the first set corresponds to the document number, which in this case ranged from 1 (one) to 12 (twelve) based on the number of participating undergraduates, and the second set refers to the specific record unit found within the analyzed corpus. It is important to note that the numbers were assigned in alphabetical order of the undergraduates' names, which will remain confidential. For example, the code QU1.1 refers to (Q: questionnaire, U1: undergraduate 1; 1 record unit 1) and so forth, as detailed in the subsequent section.

The qualitative analysis of the undergraduates' responses was aimed at interpreting subjectivity, not to uncover definitive truths or provide unquestionable answers. Instead, the analysis focused on understanding the complexity embedded within the expressed or implied intentions of the participants concerning the interactions between Science, Technology, and Society within the Biological Sciences curriculum.

3 RESULTS AND DISCUSSION OF THE PERCEPTIONS OF UNDERGRADUATES IN BIOLOGICAL SCIENCES ON THE EXISTING RELATIONS BETWEEN SCIENCE, TECHNOLOGY, AND SOCIETY

In exploring how fourth-year undergraduates in the Biological Sciences course conceptualize the acronym Science, Technology, and Society, several key elements emerged from their perceptions. These included: a) risks and benefits associated with scientific products (23.07%), b) scientific and technological determinism (7.69%), c) the application of science and technology in society (15.69%), d) a movement aimed at developing critical citizens regarding ST (7.69%), e) a view of the interdependence between science, technology, and society (7.69%), f) STS as an educational approach that promotes social participation and acknowledges the values inherent to scientific and technological development (23.07%), and g) a lack of response or knowledge on the subject (23.07%).

When defining STS relations: **QU1.14** stated, *"How science and technology can* ***influence people's lives*** *in both negative and positive ways";* **QU3.14** noted, *"The role of science in* ***enhancing societal development****";* **QU5.14** observed, *"These themes, when integrated and analyzed,* ***significantly impact our society****."* These undergraduates indicate a perception of development as a one-directional pathway influenced solely by Science and Technology. This perspective corresponds with Merton's (1938) definition of science and technology as autonomous systems with their own norms and rules, isolated from societal influences. This view overlooks the contributions of its contributors such as scientists and the pharmaceutical industry, as well as the needs and desires of the consumer society, and religious, political, and cultural beliefs of each era. It suggests that science does not operate in a vacuum and is indeed influenced by societal factors, as argued by García, Cerezo, and Luján (1996) and Shinn and Ragouet (2008).

This reductionist perspective on STS relations is also evident in the statement of undergraduate **QU6.14:** *"The contribution of science to society is indisputable; scientific discoveries and technology* ***shape the way we live in society****."*

Evidently, this perspective arises from a classical deterministic view, which posits that the direction of society is shaped by advancements in science and technology (Fabri & Silveira, 2018). This misconception is also evident in the social studies conducted by Dagnino (2007), who notes that society often perceives Science and Technology (S&T) as developing in a neutral and isolated manner, disconnected from their surrounding contexts. Such views overemphasize scientific and technological knowledge as independent and universal drivers that dictate the development of all other productive and social systems. Overlooking the historical, social, political, cultural, and ethical influences that shape S&T would be simplistic and reveal a misunderstanding of the processes that govern their development (Dagnino, 2007).

It is worth noting that this deficit in vision also falls on environmental issues. By overvaluing Science and Technology as determinants of how we live in society, there arises the risk of propagating a utilitarian and conservative vision of Environmental Education, which promotes addressing environmental problems in an ahistorical manner and ignores the social, political, and economic aspects surrounding them, pointing to technical solutions to solve current dilemmas that perpetuate the existing capitalist system, causing social exclusion (Loureiro, 2006). For example, according to Rocha, Santos, and Pitanga (2019), the current treatment of solid waste encourages the approach of the so-called Policy or Pedagogy of the 3Rs (Reuse, Reduce, and Recycle); this pedagogy is criticized because it proposes that teachers and students develop practical activities of selective waste collection without reflecting on consumerism and the social and environmental problems that emerge from this theme. Thus, it treats consumption as an unsustainable bias and not as a cultural problem to be modified, reinforcing the prevailing capitalism at the heart of destructive actions towards the environment.

Environmental Education rooted in conservatism emphasizes "the cognitive aspect of the pedagogical process, believing that imparting the correct knowledge will enable individuals to comprehend environmental issues, thereby transforming their behavior and society" (Guimarães, 2004, p. 27). However, this approach proves ineffective as it removes context from reality and prioritizes individualism over collectivity; it also adopts a reductionist and fragmented outlook, focusing solely on the conservation and preservation of nature. Consequently, it produces individuals who possess a superficial understanding of the current dynamics between society and nature that contribute to significant environmental degradation and social inequality (Amaral; Silva; Miguel; Lima; Cutchma, 2018).

In the following statement by an undergraduate, the relationship between STS is exemplified through the application of Science and Technology within societal contexts:

> ***QU7.14:*** *"This examination of how information and utility are transferred among various entities (Science, Technology, and Society—STS) can be illustrated by the example of sugarcane juice pasteurization, which was developed to prevent the transmission of Chagas disease. Initially, this technique was based on the practical knowledge of an individual who discovered that boiling and subsequently cooling the juice prevented illness—**common knowledge within the community**. This empirical knowledge was later brought to a university, **where scientific studies were conducted to formally validate the practice**. Upon confirmation of its efficacy, the process was refined to establish standardized temperatures and pasteurization techniques. This technology has since been adapted and applied in multiple contexts."*

The response from the undergraduate, emphasizing the necessity for the scientific method to validate knowledge, invites reflection on the nature of scientific rationality as depicted by Merton (1938) and Bacon (1973). These scholars consider science as a distinct and superior body of knowledge, autonomous from other social systems. Alternatively, Popper's (1982) criticism of the inductive method challenges this view, suggesting that if induction possesses any logical basis, it must inherently follow its own norms and rules sufficient to elucidate reality. Despite their differing perspectives, these authors collectively endorse the use of scientific knowledge, particularly the scientific method, as the quintessential means to comprehend reality.

This concept of scientific rationality, which positions science as a superior form of knowledge compared to other social knowledge systems, appears to have evolved within the disciplines of philosophy and sociology. Vogt and Polino (2003) suggest that while science is a significant source of knowledge, it is not necessarily the predominant one. It is crucial to clarify that this discussion is not a critique of scientific rationality; rather, it aims to acknowledge that there are multiple methods to analyze and comprehend the complexities of our world. Furthermore, the scientific method is itself influenced by historical contexts and should be recognized as such.

In the context of Science, Technology, and Society (STS) education, a primary objective is to rectify misconceptions concerning the construction, development, and progress of these interconnected domains, particularly the undue emphasis on scientific rationality. However, scholarly analysis within the field of Science Education reveals that reductionist and fragmented approaches frequently impede this objective (Aikenhead, 1994; Auler & Delizoicov, 2001). The forthcoming statements from undergraduates underscore several of the aims associated with STS education:

> **QU9.14** *"This educational approach is designed to explore the relationships between science, technology, and society by engaging students with* ***complex scenarios*** *that* ***require solutions****. It aims to empower students as they are* ***integral members of society and potential agents of change****."*
> ***QU11.14*** *"These studies concentrate on the intricate links among science, technology, and society, incorporating* ***knowledge*** *from the* ***political, popular, philosophical, and scientific*** *spheres."*
> ***QU12.14*** *"I perceive it as* ***a more integrated educational method*** *that enhances connections and mainly* ***increases awareness*** *of the significance of the interactions between Science, Technology, and Society."*

As highlighted in the discussions, STS education involves the use of problem-based scenarios that encourage students to develop skills in oral and written communication, idea discussion and debate, real-world problem solving, and collaborative learning. This approach aims to enable students to analyze, discuss, and make informed decisions to address societal challenges in their environments. It is crucial in these discussions to consider the value-based, cultural, and ethical dimensions of scientific and technological development, with the goal of providing a comprehensive education that equips students to make responsible decisions across a spectrum from personal to societal levels, thereby enabling them to become active agents of change. However, it is important to note that "just as there is no single scientific method, there is no single decision-making method" (Santor & Mortimer, 2001, p. 100). Despite the diversity of approaches available, such as addressing socio-scientific or socioenvironmental issues, employing investigative methods, and analyzing complex situations, it is essential to acknowledge the intricate nature of the decision-making process in all instances.

We also discerned within the undergraduates' definitions several aspects pertinent to the critical formation of STS relations, which are aligned with the origins of the associated social movement:

> **QU13.14** *"****This movement investigates the interconnections among Science, Technology, and Society*** *with the objective of highlighting the societal significance of science and technology. It strives to bridge the gap between society and* ***scientific culture****,* ***challenging*** *the misconception that* ***science is exclusively for*** *scientists, and thus* ***cultivating a more critically engaged citizenry****."*

The Science, Technology, and Society relationships originated from social, cultural, and pacifist movements during the mid-1960s and 1970s. Faced with environmental and social risks, and the paths taken by scientific and technological advancements, there was a recognized need to engage public opinion in decision-making processes concerning these issues. As a result, a society emerged that was critically aware of the consumption of ST products and the social and environmental impacts involved in their development (García, Cerezo, & Luján, 1996; García Palacios et al., 2003). Over the years, this awareness contributed to one of the goals of STS education: to democratize the control over Science and Technology, challenge the presumed neutrality of science, and the prevailing model of social progress. This approach empowers citizens to actively participate in decision-making processes, aiming for the common good, as "decision-making in a democratic society inherently involves public debate and the pursuit of solutions that reflect the majority's interests" (Santor & Mortimer, 2001, p. 101).

Concurrent with the historical context marked by outrage over the environmental impacts and social inequality driven by advances in Science and Technology, which fueled the rise of the Science, Technology, and Society movement, the concept of Environmental Education began to gain traction globally starting in the 1960s. This development gained political and ecological significance, calling for resolutions to the environmental and social crises that intensified during the post-industrialization era, as documented by Cavalcanti, Costa, and Chrispino (2014, p. 28):

> Environmental Education (EE) arises in this context, amidst a period marked by turbulence and societal inquiry, concurrent with the Science-Technology-Society (STS) movement. This movement highlights the influence of technoscience on society and underscores the growing divide between scientific and technological advancements and social well-being.

Since then, environmental issues have been prominently addressed at major international conferences, leading to significant agreements aimed at enhancing the relationship between humans and nature. Noteworthy examples include: the Conference on Education at Keele University in 1965, which focused exclusively on the reductionist and simplistic aspects of nature conservation; in contrast, the Stockholm Conference in 1972 fostered deeper contemplation on ecological awareness, with the objective of catalyzing a global response to the emerging socio-environmental crisis. Following the Stockholm conference, Environmental Education started to feature prominently in nearly all environmental forums, which contributed to the establishment of the United Nations Environment Programme (UNEP) (Brazil, 2011; Cruz, 2018).

Following the adoption of the neoliberal economic model in the 1970s, which led to increased anthropogenic impacts on nature to fulfill capitalist market demands, the First Intergovernmental Conference of Tbilisi took place in 1977. This conference marked a significant milestone in the field of Environmental Education by establishing key directives, including a) the interdisciplinary approach to Environmental Education; b) the necessity of its integration across all stages of formal and informal education; and c) the recommendation to analyze environmental issues at local, regional, national, and international levels, assessing their complexity (Brazil, 2011; Cruz, 2018).

Among other significant conferences, the Rio-92, held in Rio de Janeiro in 1992, stands out. This conference reaffirmed the Tbilisi guidelines for Environmental Education and steered educational efforts towards sustainable development, aiming for a harmonious coexistence between society and nature. During Rio-92, critical documents were formulated to facilitate this goal, including Agenda 21, the Earth Charter, and the Treaty on Environmental Education for Sustainable Societies, which emphasize global responsibility. These documents are intended to direct activities within educational settings (Brazil, 2011; Cruz, 2018).

Although the undergraduates did not explicitly discuss environmental issues in the context of the origins of the Science, Technology, and Society movement, at its heart, the STS movement is intrinsically linked with Environmental Education. It promotes the understanding and adoption of development practices grounded in the sustainability of societies. This includes a critical examination of how environmental resources are utilized, from mineral extraction to forest exploitation and water consumption. Additionally, it encourages a deeper reflection on the various facets of the human-nature relationship, recognizing that environmental imbalances can impact all ecosystems.

Finally, to conclude the discussion of the undergraduates' perspectives on STS, we identify a vision that highlights the interdependence within the triad of Science, Technology, and Society:

> ***QU10.14: "****It serves as the cornerstone of innovation, given that scientific research necessitates the use of technologies, which in turn require support from society. Thus, society is dependent on science, just as science depends on technology."*

"In summary, ***the three walk together, side by side****."* This statement, while not offering specific metrics to gauge the depth of the undergraduates' understanding or the practical applications of STS relationships, does confirm their grasp of the principle of interaction within the triad. According to Santos and Mortimer (2001), the STS approach aims to illuminate how social, cultural, and environmental contexts shape the production and application of science and technology. Additionally, it examines how science and technology reciprocally influence these contexts and explores the mutual effects between them, thus revealing their interconnections.

Although only 23.07% of the students were unable to define STS, the majority (53.84%) expressed uncertainties about the nature, application, and dissemination of this relationship, as evidenced in the subsequent statements:

> ***QU1.17: "How could this negatively impact society****?"*
> **QU3.17:** *"What would be the appropriate approach in this context?"*
> **QU4.17:** *"I am interested in exploring further how STS influence daily life.* ***It's clear that there are societal forces that shape demand****, whether it's through a fanatical leader or a system that undermines critical thinking in Brazil. Is there a strategy to prevent such issues from becoming normalized?"*
> ***QU5.17: "How can this concept be popularized?*** *What are the main challenges? How does it benefit the population?"*
> **QU6.17:** *"****The discourse around Science, Technology, and Society is not yet widely engaged or debated****. Consequently, individuals of any educational background should be able to comprehend the vast progress and achievements within these fields."*
> ***QU09.17:*** *"What impact does STS have on society?"*
> ***QU13.17:*** *"Educating from an STS perspective* ***is purported to enhance individuals' abilities to engage in informed decision-making. How can this objective be realized in the short term****, especially considering the current Brazilian context and the decision-makers of today? How can they be brought to understand through an STS lens?"*

Undergraduate Q**U1.17** displayed a limited understanding of the nature of science and technology, which are subject to manipulation by groups seeking to benefit themselves or specific cohorts, thereby posing risks and causing harm to both the environment and people. This is evident, for example, in the impact of industrial automation, which, while creating jobs, also illustrates the dual nature of scientific and technological progress—yielding both losses and benefits. This ambivalence often results in advantages for some at the expense of others, as highlighted by Angotti and Auth (2001, p. 17):

> While in the realm of discourse technological advances aim to improve living conditions for the population, in everyday practice, what is observed is an exacerbation of these conditions, especially among already disadvantaged populations. An example of this is the adoption of policies aimed at creating or maintaining jobs. Not only have these policies failed to solve the unemployment problem in the country, but they have also led government officials to "bow" to the "power of capital," granting privileges to wealth holders and further increasing social exclusion [...].

The perception of the relationship among profit, power, and exclusion within the context of Science and Technology is evident in the remarks made by undergraduate **QU4.17.** This student acknowledges the influence of group interests on the direction of scientific and technological production but also expresses difficulty in comprehensively grasping the intricate STS relations. Oliveira (2020) notes that it is simplistic to view ST as exclusively beneficial, neutral, and universally accessible. Typically, those who establish the rules of production are the ones who benefit most, with these rules often being shaped by the political and economic domains.

Meanwhile, undergraduates **QU13.17** and **QU6.17** voiced concerns about how to achieve and popularize Science, Technology, and Society goals in contemporary society on a short-term basis. Realizing STS objectives quickly presents a significant challenge due to the complexities of its concepts and the constraints posed by the social, cultural, capitalist, and educational systems. Additional individual factors, such as a lack of interest in the subject, learning difficulties, and limited access to information about ST, further complicate these efforts. Beck (2010) describes contemporary society as a "risk society," defining risk as the anticipation of a catastrophe. Accordingly, society, irrespective of class or social group, inherently engages in reflecting on its actions and adopts measures for debate, prevention, and management of self-generated risks, involving some degree of participation in ST-related decision-making.

Exploring undergraduates' perceptions of Science, Technology, and Society, they were queried about whether the use of technologies would result in the creation of more jobs than it eliminates. Of the responses collected, 61.53% indicated that automated services decrease employment opportunities, particularly for the lower socioeconomic classes with limited education. Conversely, 30.76% argued that the use of technology does not harm but rather enhances people's lives by creating more jobs, especially for those with higher education levels. Meanwhile, 7.69% of respondents were unable to provide an opinion. For example:

> ***QU1.23:*** *"No, I believe that* ***as technology becomes more prevalent*** *in industrial settings,* ***fewer people will be hired*** *because many tasks can now be accomplished by a simple machine or robot."*

> ***QU6.23:*** *"I agree. The replacement of manual services with automated systems, due to their **higher productivity**, will result in **increased unemployment rates**."*

As illustrated by the undergraduates' comments above and according to Roggia and Fuentes (2016), the prominence of industrial automation has been escalating since the first Industrial Revolution in the 18th century in England. Historically, humans have utilized technology, developing mechanical machines and devices to reduce physical effort and enhance task productivity, exemplified by the invention of wheels for transporting heavy loads and windmills powered by wind or animal force. However, alongside the advancements in robotization, computerization, the automotive industry, and other industrial sectors, there has been a marked increase in unemployment. This trend raises questions about the validity of a direct correlation between scientific-technological progress and human development. Despite being a field with potential, it is challenging to assert that the rise in unemployment due to advancements in science and technology can be compensated by further scientific and technological production. Increased competitiveness and productivity typically lead to more technological development but result in fewer employment opportunities (Auler, 2002).

Despite technological advances benefiting a small segment of the population skilled in operating machinery and developing projects in fields such as robotics, the majority of the lower and middle social classes, who are in need of employment, find themselves increasingly marginalized from the labor market. This marginalization leads to abandonment and social exclusion. Auler (2002, p. 101) encapsulates this dynamic, stating: "Power today exploits and oppresses not through the use of direct action [labor], but by ignoring, failing to intervene, refusing to act, and hiding behind complex and perfectionist procedures."

The perception of technology exclusively as a benefactor derives from focusing only on the aspects that deliver conveniences, comfort, and wealth, while overlooking its detrimental side effects, such as unemployment. This view is also based on the belief that scientific and technological knowledge is produced solely through traditional epistemic factors inherent to Science and Technology, as noted by Auler (2002), and is free from any external influences such as historical, social, political, economic, or religious factors, which might adversely affect decisions related to the production and utilization of technology.

This perspective on social development, rooted in the Linear Model of Innovation, is clearly reflected in the responses of the undergraduates when they were asked about the significance of scientific research. In this instance, all respondents associated the economic development of the country with investments in research, as evidenced in the following statements:

> ***QU5.27: "****[...] Research is pivotal for national development, as **investments in research are key to fostering innovation**."*
> ***QU6.27: "****[...] **Research forms the cornerstone of development**; lacking it, the nation remains oblivious to its actual conditions and the potential changes that actions might bring."*
> ***QU9.27: "****[...] I consider it fundamentally important because **it contributes significantly to the country's economic development.**"*
> ***QU12.27:*** *"[...] I believe that a substantial part of a country's **economic growth** is derived from **scientific research**."*
> ***QU13.27: "****[...] **Advancements and improvements** across all sectors are pursued through ongoing research."*

In this scenario, the development of society, reflected in enhanced social well-being, is seen as a direct outcome of economic growth. This growth is dependent, according to the linear model of innovation, on investments and advancements made in scientific and technological applications. However, historical observations reveal that scientific and technological development does not always equate to economic growth, nor does it necessarily lead to social development. The trajectory of scientific and technological progress often unveils negative consequences, such as harm to human health and the environment. Furthermore, it is evident that the direction of scientific and technological activities is shaped by political decisions. These decisions frequently prioritize research that generates profits for specific groups at the expense of broader social benefits, particularly affecting the less privileged classes and favoring economically dominant groups (Auler, 2002).

Moreover, scientific research and technological products embody the interests and desires of society or dominant social groups that are driven by profitability. For instance, there is currently a significant consolidation of chemical industries into large transnational corporations that control the production and consumption markets. A notable example is the pesticide industry, which not only contributes to health issues but also collaborates closely with the pharmaceutical sector to supply medicines, thus profiting from both creating the demand and providing the solution (Carneiro et al., 2015). Evidently, society also plays a role in shaping the focus of scientific and technological research, whether through its needs, rampant consumerism, or the pursuit of profits that underpin capitalism.

As Auler (2002) points out, it is essential to convey in societal discourse that Science and Technology are not the antagonists in the narrative, nor are they solely bearers of beneficial outcomes. They are influenced by social, cultural, and historical factors. Furthermore, it is crucial not to label science and technology as inherently good or bad, as their impacts can vary greatly depending on the societal or contextual needs. Therefore, it is more accurate to view them as a two-sided coin, influenced by societal interests that guide their application based on the specific intentions of each context (Auler, 2002).

4 CONCLUSION

In this investigation of fourth-year Biological Sciences undergraduates' understanding of the interactions between Science, Technology, and Society, it was revealed that they acknowledge the influence of external social, historical, political, and economic factors on the epistemology of Science and Technology. These factors shape the directions of their development and applications. Consequently, they recognize that the process of scientific and technological development is not neutral, as it is designed to satisfy the desires and needs of society and the interests of specific groups. These groups are often connected to the country's economic or political power, with a focus on profitability.

On the other hand, the undergraduates' statements reveal misconceptions about the nature of scientific and technological development, particularly when they consider scientific and technological research as a determining factor for the country's economic development. This perspective aligns with the Linear Model of Innovation, which excessively values science and technology as superior, unquestionable forces dictating the course of economic and social progress. Reinforcing this viewpoint, the undergraduates emphasize the scientific method as the sole reliable means to explain reality, overlooking its historical and social dimensions.

In relation to the environment, this aspect was "overshadowed" in the responses of the undergraduates, as it was not mentioned in discussions about the processes of construction and application of Science and Technology or in the context of STS Education objectives. However, in Brazil, despite global concerns about various environmental issues, particularly the ongoing climate changes that have led to severe consequences, there has been limited focus on the role of Environmental Education in addressing and mitigating the climate emergency through educational actions and policies.

It is concluded that the undergraduates recognize factors inherent to the Science, Technology, and Society relations as previously mentioned. However, due to the inherent complexity of these interactions and other aspects and limitations related to the educational process, there are emerging doubts and misconceptions or incomplete understandings that need to be addressed.

In this context, STS Education and Environmental Education are underscored as crucial educational strategies. These approaches are key in correcting distorted perceptions of the nature of Science and Technology, the Linear Model of Innovation, and the supposed neutrality and rationality of scientific thinking. Moreover, they are vital for promoting reflective processes and critical participation among undergraduates in both individual and collective decision-making. This is particularly important in the application of science and technology and, fundamentally, in addressing the ongoing climate emergency.

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