



**Sequence of Activities on the Exploration of Cassiterite in the Light of the
Science, Technology, Society and Environment Approach**

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ABSTRACT

The purpose of this study was to examine the results of a sequence of activities to discuss the exploitation of cassiterite on indigenous lands with regard to education for sustainability, based on the postulates of the Science, Technology, Society and Environment approach (AIKENHEAD, 2005, 2009; AULER, SANTOS, 2011), with the systematization of the sequence of activities based on the proposal of the three pedagogical moments (DELIZOICOV, ANGOTTI, PERNAMBUKO, 2011) in a first year high school class, in the subject of Chemistry at a public school in the state of Espírito Santo/Brazil. This is a qualitative case study, using systematic observation to collect data (GIL, 2022), analyzed in the light of Bardin (2011). The magnitude of the study lies in the fact that there are few studies contributing to its originality. The research contributed to offering a proposal for pedagogical practice with a sustainable perspective in science teaching, going through debates on scientific, technological, social and environmental aspects. As a result, moments of debate situations were provided that fostered an interdisciplinary approach, enabling students to advance in their understanding of the importance of mining in a sustainable and responsible way.

KEYWORDS: STSE. Pedagogical practice. Mineral resources.

1 INTRODUCTION

Illegal mining activities, cassiterite in particular, were reported in Yanomami indigenous lands and their protected areas in the state of Roraima, Brazil's northern region, in February 2023. In the last two years, Cassiterite, commonly known as black gold, has attracted the interest of illegal miners in Roraima.

In 2021 and 2022, when there were no mines authorized by the National Mining Agency, this Brazilian state exported 733 tons of cassiterite and its derivatives. Professor Giorgio de Tomi, who coordinates a research group in the mining sector at the University of São Paulo, highlighted in a report that mining activities are vital for the country but their potential environmental and social damage cannot be ignored, which may affect society as a whole.

The report of the International Commission on Education for the 21st Century, coordinated by Jacques Delors, to UNESCO (United Nations Educational, Scientific and Cultural Organization), in the pursuit of quality education, advocates the importance of education throughout life. Favoring the discussion of four fundamental educational pillars – learning to know, learning to do, learning to live together and learning to be –, which conjecture an education that prepares students for life in society.

In education, through sustainability, pedagogical practices can emerge based on scientific, technological, social and environmental aspects (LEITE; TERRA; BRASIL, 2016) and gain prominence, which then can promote the construction of scientific knowledge (VASCONCELOS; CAMPOS, 2021), (LEITE; SGARBI; FREITAS, 2012) and (KRUGER; LEITE, 2013). From this perspective, an educational approach was chosen based on the focus on Science, Technology and Society (STS). Education focusing on STS, for Aikenhead (1994), is also important to support social responsibility in decision-making:

STS science is also expected to fill a critical void in the traditional curriculum -- the social responsibility in collective decision making on issues related to science and technology. Such issues require a harmonious mix of a scientific-technical elite with an informed attentive citizenry. Together both groups will need to make complex

decisions that involve the application of scientific knowledge, technological expertise, social understanding, and humane compassion (AIKENHEAD, 1994, p. 48).

Facing the environmental crisis and in search of sustainable quality education, several authors defend the incorporation of the letter E (environment) to express the STS movement, becoming STSE (Science, Technology, Society and Environment), which will benefit greater focus on environmental consequences, relating to technological and scientific development.

A new praxis and a new ethics is needed, which must mediate the decision-making processes, to promote a sustainable present and future, that is, “reinforce this convergence of the STSE movement and Environmental Education in the research and educational innovation, to form a citizenship capable of contributing to decision-making” (VILCHES; PÉREZ; PRAIA, 2011, p. 205, our translation¹).

Rios and Solbes (2007) also highlight the need to introduce STSE in education:

The introduction of STSE relationships is basic in the teaching of technology and science because it gives a multidimensional idea of the various factors that intervene in the solution of scientific and technological problems, in addition to giving a broader historical view and a better contextualization of the contents taught. By carrying out these types of activities, students in Higher Training Cycles change their convictions of technology and science and improve their attitude towards them (RIOS; SOLBES, 2007, p. 1, our translation²).

According to researchers, like Cachapuz et al. (2011), Rosa (2007) and Rios and Solbes (2007), the introduction of STSE relations is essential in technology and science education, as it provides a multidimensional view of the various factors involved in problem solving (AIKENHEAD, 2005; 2009).

As stated by Teixeira (2020), some aspects of the STSE approach are relevant for the planning of education related projects. It comprises a

[...] conception of emancipatory education, aimed at a critical development project so that people could be more critical in relation to the exclusionary society we live in, considering the most varied aspects; and that they seek, using the teaching and knowledge they receive, alternatives for social transformation.

The goals of science education, alongside other subjects and activities experienced by students in schools, focused on the development of citizenship and the constitution of a socially significant scientific culture.

Teaching contents that adequately englobe aspects of Science, Technology and Society, characterized by the treatment of social themes that interest students and show relevance to society as a whole, in which scientific contents (concepts, attitudes and skills) are instruments for social engagement and to support well-founded decision-making processes.

¹ “reforzar esta convergencia del movimiento CTSA y de la Educación Ambiental em las tareas de investigación e innovación educativa, para formar una ciudadanía susceptible de contribuir a la toma de decisiones”

² “La introducción de las relaciones CTSA es básica en la enseñanza de la tecnología y las ciencias porque da una idea multidimensional de los diversos factores que intervienen en la solución de problemas científicos y tecnológicos, además de dar una visión histórica y una contextualización de los contenidos enseñados. Al realizar actividades de este tipo los estudiantes de Ciclos Formativos Superiores cambian su imagen de la tecnología y las ciencias y mejoran sus actitudes hacia las mismas”

Teaching strategies and resources designed to create dynamic activities, within a development atmosphere defined by student participation, interactive and dialogical methods of study, and dissemination and discussion of socioscientific issues.

Process-centered assessment, always seeking to improve classes, courses and other training processes, in an attempt to ensure consistent quality learning and training for everyone (TEIXEIRA, 2020, p. 21-22, our translation³).

In this aspect, the STSE approach in the educational environment, in science teaching, points to an attempt to form scientifically and technologically literate citizens (CHASSOT, 2018), capable of making decisions. Hence, the STSE movement is an innovative educational indication that seeks to include science and technology in its social context, bringing closer the mutual relationships between scientific and technological development and social processes (AIKENHEAD, 2005; 2009).

The purpose of the STSE movement would be to grasp the nature of science and its importance in society, which suggests the need for students to acquire essential information about science (CHASSOT, 2007) to encompass the potentialities and obstacles of scientific knowledge (SANTOS; SCHNETZLER, 2003). From this perspective, for Chassot (2003),

science literacy is considered an emerging area in science teaching, which involves knowledge of the daily practices of science, scientific language and the decoding of the beliefs attached to it. Some advocate that we should look for the knowledge present in the daily lives of the general public, in particular the one presented inaccurately by the media to public opinion. These are the proposals that see science literacy as a possibility to correct distorted teachings. I believe we can think more broadly about the possibilities to make students, by understanding science, better understand the manifestations of the universe. This broader approach is defended here, but the other tendency of making corrections to teachings that are presented distorted is still recognized as valid (CHASSOT, 2003, p.91, our translation⁴).

³ “concepção de educação emancipadora, voltada para um projeto de formação de pessoas críticas em relação à sociedade excluente em que vivemos, considerando os mais variados aspectos; e que busquem, instrumentalizados pelo ensino e conhecimentos que recebem, alternativas para a transformação social. Objetivos da educação científica, junto com as demais disciplinas e atividades vivenciadas pelos estudantes nas escolas, centrados na formação da cidadania e na constituição de uma cultura científica socialmente significativa. Conteúdos de ensino que articulem adequadamente aspectos da Ciência, Tecnologia e Sociedade, marcados pelo tratamento de temas sociais de interesse para os alunos e de relevância para toda a sociedade, em que os conteúdos científicos (conceitos, atitudes e habilidades) sejam instrumentos para a participação social e para subsidiar processos de tomada de decisão bem fundamentadas. Estratégias e recursos didáticos mobilizados para criar atividades dinâmicas, dentro de uma atmosfera formativa marcada pela participação dos alunos e por métodos interativos e dialógicos de estudo, difusão e discussão de questões sociocientíficas.”

⁴ “a alfabetização científica está colocada como uma linha emergente na didática das ciências, que comporta um conhecimento dos fazeres cotidianos da ciência, da linguagem científica e da decodificação das crenças aderidas a ela. Há aqueles que advogam que se deva procurar especialmente conhecimentos que estão no dia-a-dia do grande público, em particular os que são apresentados com imprecisão pelos meios de comunicação à opinião pública. Essas são propostas que vêm a alfabetização científica como uma possibilidade para fazer correções em ensinamentos distorcidos. Acredito que se possa pensar mais amplamente nas possibilidades de fazer com que alunos e alunas, ao entenderem a ciência, possam compreender melhor as manifestações do universo. Aqui se defende essa postura mais ampla, mesmo que se reconheça válida a outra tendência, de fazer correções em ensinamentos que são apresentados distorcidos.”

Therefore, science literacy to society is a continuous process and demands permanent acquisition of new knowledge (MARANDINO, 2003). In this pedagogical practice, focusing on sustainability education, an STSE theme was carried out on mineral resources, specifically cassiterite, which is a natural dioxide, with tin (a chemical element with the symbol Sn, located in Group 14 and in the 5th period of the periodic table) as its primary ore. Tin is used, for example, in metallicalloys, soldering, and the coating of metal plates. Cassiterite found in nature is an oxide that may also contain traces of some other chemical elements such as iron, zinc, manganese, gallium, niobium, tungsten, indium, and scandium.

This research aims to present a pedagogical practice in science teaching, promoting an approach in line with the STSE (Science, Technology, Society, and Environment) approach, with potential discussions on sustainable development. It also enables the replicability of the educational intervention with a socio-environmental focus on cassiterite and its implications for society. Furthermore, academic relevance is achieved because there are few studies on this topic in basic education, which contributes to its originality.

2 OBJECTIVE

This study aimed to understand a pedagogical practice planned based on the proposal of the three pedagogical moments (DELIZOICOV, ANGOTTI E PERNAMBUCO, 2011), in order to address cassiterite exploitation in chemistry syllabus with epistemological discussions in light of the STSE approach.

3 METHODOLOGY

In this qualitative research (GIL, 2022), a case study, systematic observations were conducted for data collection and then analyzed in the light of Bardin (2011). The data collected were used solely for this study, and no personal information of the participants was disclosed, in accordance with research ethics guidelines. The activity was carried out with a group of first-year high school students in Chemistry classes of a public state school in Serra, in the state of Espírito Santo.

4 DISCUSSION

The pedagogical practice was outlined as a sequence of activities based on the three pedagogical moments proposed by Delizoicov, Angotti and Pernambuco (2011): Initial Questioning, Organizing Knowledge and Applying Knowledge.

Among other possibilities for establishing a teaching dynamic in the classroom that encompasses the aspects presented here, the following, which has been part of some educational initiatives, is given as an option. It is characterized by what has been called pedagogical moments, each moment with specific and differentiated functions,

namely: initial questioning, organizing knowledge, and applying knowledge (DELIZOICOV, ANGOTTI, PERNAMBUCO, 2011, p. 201, our translation⁵).

Initial Questioning, the first pedagogical moment, is the analysis of the reality in which one of the main goals is to problematize the knowledge students are unveiling. The highlight of this initial questioning is to make the student feel the need to acquire different knowledge that they do not yet possess. In other words, it is about framing the circumstance as a problem to be addressed.

The second pedagogical moment, Organizing Knowledge, involves supervising the reality study addressed in the first moment. During this moment, the essential knowledge necessary for understanding the topics and the initial questioning studied are now selected and systematized, this entails the systematic organization of the study. According to Delizoicov, Angottie Pernambuco (2011):

A wide range of activities are put into practice so that the teacher can develop the conceptualization identified as essential for scientific understanding of the problematized situations. It is at this moment that problem-solving and exercises, such as those proposed in textbooks, can play their formative role in the acquisition of specific knowledge. However, as said before, this is just one aspect of the necessary problematization for students' education (DELIZOICOV, ANGOTTI, PERNAMBUCO, 2011, p. 201, our translation⁶).

Applying Knowledge, the third pedagogical moment, involves the use of scientific knowledge in meaningful contexts, aiming to deal with the learner's incorporated knowledge in their cognitive structure. This is done in order to interpret and reason the initial circumstances that prompted their study and other situations.

The three pedagogical moments were organized through a sequence of activities. As stated by Auler e Bazzo (2001), school activities can be enhanced by favoring an educational approach that englobes scientific, technological, social, and environmental aspects, promoting the intertwining of knowledge in pursuit of interdisciplinary education, especially in basic education.

The starting point, then, was the assumption of exploring cassiterite in illegal mines in indigenous lands in Roraima, Brazil, to develop a sequence of activities following the three pedagogical moments approach (DELIZOICOV, ANGOTTI, PERNAMBUCO, 2011). Thus, promoting connections with chemistry knowledge through the STSE theme regarding

⁵ “Entre outras possibilidades de estabelecer uma dinâmica de atuação docente em sala de aula que contemple os aspectos aqui apresentados, a seguinte, que tem feito parte de algumas iniciativas educacionais, é fornecida como opção. Ela é caracterizada pelo que tem sido denominado de momentos pedagógicos, distinguindo três deles com funções específicas e diferenciadas entre si, a saber: problematização inicial, organização do conhecimento e aplicação do conhecimento”

⁶ “As mais variadas atividades são então empregadas, de modo que o professor possa desenvolver a conceituação identificada como fundamental para uma compreensão científica das situações problematizadas. É neste momento que a resolução de problemas e exercícios, tais como os propostos em livros didáticos, pode desempenhar sua função formativa na apropriação de conhecimentos específicos. No entanto, conforme se tem destacado, esse é apenas um dos aspectos da problematização necessária para a formação do aluno.”

“cassiterite.” This approach allows for an interdisciplinary approach, aiming for sustainable education with high school students, bridging disciplinary boundaries.

In Table 1, the dynamics and activities conducted during the three pedagogical moments are presented and explained. The lesson plan was done with a morning group of first-year high school students and spread across four 50-minute Chemistry classes.

Table 1 - Lesson planning of the sequence of activities

THEME: CASSITERITE	
Approach: STSE Method: Three pedagogical moments	
STAGE	INITIAL QUESTIONING
Activity/class	Procedures
Discussion 1 class	<ul style="list-style-type: none"> - First talk about illegal mining in indigenous lands and mineral extraction, based on their previous knowledge; Introduction to the chemical properties of cassiterite; - Reading of a scientific article on illegal mining in indigenous lands; - Article discussion; - Watch a video about illegal mining in the Yanomami indigenous lands. Available at: https://globoplay.globo.com/v/11359597/. Accessed on March 20th, 2023.
STAGE	ORGANIZING KNOWLEDGE
Activity/class	Procedures
Research 2 classes	<ul style="list-style-type: none"> - Group work: search on school's Chromebooks about: environmental and social impacts of illegal mining; the importance of legal mining for society and sustainability; the chemical properties of tin and its technological applications; - Content review of the periodic table and exercises.
STAGE	APPLYING KNOWLEDGE
Activity/class	Procedures
Socialization 1 class	<ul style="list-style-type: none"> - Groups' presentations about illegal mining, mining and tin, followed by a discussion with the whole class; - Final activity: make a word cloud about cassiterite using the Mentimeter tool.

Source: Developed by the authors, 2023.

In the first pedagogical moment, Initial Questioning, a previous assessment of students' knowledge was conducted regarding illegal mining in indigenous lands and mineral extraction, as well as the chemical properties of cassiterite. After this, a scientific article about illegal mining in indigenous lands was read, and there was a text discussion focused on socio-environmental and sustainable aspects. Later, the students watched a video about illegal mining in Yanomami indigenous lands and the socio-environmental damages caused by it. After the video, it was noticeable that the students were deeply affected, some even mentioned that they were unaware of this situation and that they appreciated learning about it.

In the Organizing Knowledge phase, a group research activity was carried out using the school's Chromebooks. Students researched about environmental and social impacts of illegal mining, the importance of legal mining for society and sustainability, the chemical properties, and the technological applications of tin. Following this research, a review of the periodic table and exercises to practice it were done.

Finally, in the Applying Knowledge phase, the groups presented their research and discussed the topics with the whole class. The lesson plan concluded with students working collaboratively to create a word cloud on the cassiterite theme and its technological, scientific, social, and environmental implications, using the Mentimeter tool. A QR Code was provided on one slide so that the students could access and contribute as many times as they wanted with words/terms related to the cassiterite theme. The outcome of the collaborative creation of the word cloud is shown in Figure 1.

Figure 1 - Collaborative creation of the word cloud by the students.



Source: Mentimeter tool, own elaboration, 2023.

During the last discussion with the students, the result of the word cloud was briefly highlighted. The students noticed the extended scope of words/terms that went beyond the chemistry content, such as chemical, minerals, metallic alloys, tin, industrial and societal applications. For instance, topics related to indigenous issues, water pollution and contamination, environmental damage, tragedies, tax evasion, illegal mining, responsible mining, environmental crimes, and other topics emerged, demonstrating that the discussion transcended disciplinary boundaries.

The technological, scientific, social and environmental aspects were fostered through the sequence of activities, promoting the STSE educational approach (AIKENHEAD, 2005; 2009), (LEITE; SGARBI; FREITAS, 2012), and (AULER; BAZZO, 2001). This approach facilitated interdisciplinary discussion-driven situations throughout the execution of the pedagogical practice planned based on the three pedagogical moments.

According to Cachapuz *et al.* (2011), it is necessary to offer discussion-driven moments for students in order to promote awareness, as one does not arrive at theories straightforwardly and overnight, it requires an extensive scaffolding process. It is not a mere process of accumulation but rather a shift in perception, with potential development of scientific knowledge (FOUREZ, 1995), encompassing new ways of thinking and nurturing critical thinking and decision-making awareness.

Lastly, the students discussed the importance of mineral resources, which should be extracted in a legal and sustainable way, thereby contributing to income, taxes, development, and providing legal job opportunities and economic growth for the region.

5 CONCLUSION

While planning the pedagogical practices, using the STSE educational approach (AIKENHEAD, 2005; 2009), a context of interdisciplinary discussion-driven situations was created through a sequence of activities based on the three pedagogical moments (DELIZOICOV, ANGOTTI, PERNAMBUCO, 2011).

Considering the depth of the various terms presented by the students, this knowledge transcended the boundaries of the chemistry subject and extended into other areas. This is evident in the word cloud made by students in the classroom, centered around cassiterite, as well as in the reflections that arose from the activities conducted during the pedagogical practice.

This research provided a pedagogical practice with a sustainable perspective in science teaching, focusing on scientific, technological, social, and environmental discussions (AULER; BAZZO, 2001), (AIKENHEAD, 1994), (AULER; SANTOS, 2011). The practice created opportunities for discussion-driven situations that enhanced the interdisciplinary approach, deepening the students' awareness of the importance of sustainable and responsible mining.

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