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Domains of Scientific Knowledge and Didactic Social Technologies for Promotion of Scientific and Technological Literacy

Domínios do Conhecimento Científico e Tecnologias Sociais Didáticas para a Promoção da Alfabetização Científica e Tecnológica

Dominios del Conocimiento Científico y Tecnologías Sociales Didácticas para Promoción de la Alfabetización Científica y Tecnológica

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Abstract

Since the mid-2010s, the field of Science Education has discussed the incorporation of Social Technologies (ST) into science teaching, particularly in a historical moment in which the literature highlights a perspective of Scientific and Technological Literacy (STL) committed to students' social transformation. In this context, within the school environment, the theoretical-methodological model of Didactic Social Technologies (DST) emerges, involving further the resolution of socially relevant problems, also the promotion of different dimensions of STL. Based on this proposal, this study aims to identify limits and possibilities for mobilizing the Domains of Scientific Knowledge (DSK) through the development of DST. Thereunto, the study revisits the concepts of STL and DST, discussing how these approaches can mobilize the DSK (conceptual, epistemic, social and material). Finally, we emphasize the fundamental role of teachers' intentionality in enabling this process and achieving integration among DSK, STL and DST.

Keywords: teacher intentionality, teacher education, social technology

Resumo

Desde meados da última década, o campo da Educação Científica vem discutindo a incorporação das Tecnologias Sociais (TS) no Ensino de Ciências, especialmente em um momento histórico, em que a literatura destaca uma perspectiva de Alfabetização Científica e Tecnológica (ACT) comprometida com a transformação social dos estudantes. Nesse contexto, no ambiente escolar, surge a proposta teórico-metodológica das Tecnologias Sociais Didáticas (TSD), que envolve, além da resolução de problemas socialmente relevantes, também a promoção de diferentes dimensões da ACT. Com base nessa proposta, este trabalho tem como objetivo identificar limites e possibilidades de mobilização dos Domínios do Conhecimento Científico (DCC) a partir do desenvolvimento de TSD. Para tanto, o estudo revisita os conceitos de ACT e de TSD, discutindo de que modo o uso das TSD pode mobilizar os DCC (conceitual, epistêmico, social e material). Por fim, ressaltamos o papel fundamental da intencionalidade docente para viabilizar esse processo e alcançar a integração entre DCC, ACT e TSD.

Palavras-chave: intencionalidade docente, formação de professores, tecnologia social

Resumen

Desde mediados de la última década, el campo de la Educación Científica viene discutiendo la incorporación de las Tecnologías Sociales (TS) en la enseñanza de las ciencias, especialmente en un momento histórico en el que la literatura destaca una perspectiva de Alfabetización Científica y Tecnológica (ACT) comprometida con la transformación social del estudiantado. En este contexto, en el ámbito escolar, surge la propuesta teórico-metodológica de las Tecnologías Sociales Didácticas (TSD), que implica, además de la resolución de problemas socialmente relevantes, también la promoción de diferentes dimensiones de la ACT. Con base en esta propuesta, este trabajo tiene como objetivo identificar límites y posibilidades de movilización de los Dominios del Conocimiento Científico (DCC) desde el desarrollo de las TSD. Para ello, el estudio revisa los conceptos de ACT y de TSD, discutiendo de qué modo estos enfoques pueden movilizar los DCC (conceptual, epistémico, social y material). Por último, destacamos el papel fundamental de la intencionalidad docente para viabilizar este proceso y alcanzar la integración entre DCC, ACT y TSD.

Palabras clave: intencionalidad docente, formación del profesorado, tecnología social

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Introduction

In recent decades, the debate has intensified regarding the social role of science and technology in the face of contemporary problems such as misinformation, denialism, and growing socio-environmental challenges (G. Fernandes, 2025; Lorenzetti, 2021; Silva & Sasseron, 2021). In this context, the search for educational practices capable of expanding students' critical engagement with scientific and technological knowledge and its relationship with society stands out. The emphasis is placed, in particular, on the development of Scientific Literacy (SL) (Silva & Sasseron, 2021; Sjöström, 2024; Valladares, 2021), in Scientific and Technological Literacy (STL) (G. Fernandes, 2025; Fernandes et al., 2024; Fernandes et al., 2025; Fourez, 1997, 2005; Lima, 2025; Milaré et al., 2021) and in the social nature of science (Silva & Sasseron, 2021; Silva et al., 2022).

These theoretical constructs converge towards a new perspective developing in the school context: that of Didactic Social Technology (DST) (Fernandes et al., 2024; I. Fernandes, 2025; Fernandes et al., 2025). DST is configured as a didactic-social model aimed at social transformation, incorporating and problematizing social, political, economic, and ethical themes related to science and technology, promoting spaces for discussion, reflection, and action on the part of students.

Currently, we also find studies focused on understanding the Domains of Scientific Knowledge (DSK) (Duschl, 2008; Stroupe, 2014) that have been developed in the area of Science Education to deepen the understanding of how the modes of production of science contribute to the learning process in the school context (Cappelle et al., 2023; Franco & Munford, 2021; Silveira & Munford, 2020). In turn, these DSKs establish relationships and foster the development of SL and STL (Santos & Silva, 2025; Silva & Sasseron, 2021).

Given this context, the objective of this work is to **identify the limits and possibilities of mobilizing DSKs based on the development of DSTs**. Through an analysis that articulates the theoretical framework of DSK with that of DST, both of which show potential for the development of the dimensions of STL (G. Fernandes et al., 2024), the aim is to deepen the debate on the formative and transformative potential of these initiatives in the school context, which at the same time recognize the role of science and technology in society, highlight the social character of science, and address contemporary socio-environmental demands.

Theoretical discussion proposed in this work contributes to the field of Science Education by identifying the limits and possibilities of mobilizing DSKs through the development of DSTs. The aim is to broaden the understanding of how conceptual, epistemic, social, and material domains can be articulated with teaching practices. These initiatives aim to promote the development of STL, to foster the social transformation of students.

Scientific and Technological Literacy (STL) as Social Transformation

STL has been identified as a promising construct for the formation of critical and participatory citizens in contemporary society (G. Fernandes, 2025; Fernandes et al., 2024; Fernandes et al., 2025; Lima, 2025; Lorenzetti, 2021; Milaré & Richetti, 2021; Rosa & Amaral, 2021). It is not limited to the transmission of concepts, a characteristic of a conservative educational practice; it also provides opportunities for "empowering people in the name of humanistic and/or socioeconomic goals" (Fourez, 1997, p. 903). This paves the way for individual autonomy and the ability to act and negotiate decisions in a world marked by the growing influence of science and technology. In that regard, STL aims to overcome a merely instrumental conception of knowledge and proposes to promote a critical understanding of the role of scientific and technological practices in building "a more democratic, just, egalitarian and sustainable society" (Milaré & Richetti, 2021, p. 19), encouraging the effective participation of individuals in socio-political debates and actions.

Among the pillars of STL, the following stand out: the ability to analyze scientific, technological, and social impacts, and informed decision-making aligned with the democratic purposes of knowledge. These pillars, according to Fourez (2003, pp. 213–214), involve "humanistic, social, and economic" dimensions, establishing that STL is about being able to "participate in the culture of our time," that the citizen has "autonomy in our techno-scientific society and a reduction in inequalities," in addition to the individual's participation in an industrialized world. Then, building an integrated conception of science and technology "decodes the world" for the citizen, also empowering them to understand and transform reality (Auler, 2003; Fourez, 2003, p. 113).

Therefore, ACT, from a **global** perspective[1], is configured as a construct to foster critical reflection on ethical, cultural, and political issues related to science and technology, empowering individuals to make informed decisions and act in their communities.

Within the **school** context, STL becomes relevant by providing a "critical and transformative education, guided by progressive theories" (Lorenzetti, 2021, p. 48), capable of preparing students for the challenges of the modern world. Thus, science education begins to integrate debates on sustainability, democracy, and citizenship, fostering the emergence of critical and active individuals. According to Milaré and Richetti (2021, p. 41), "the challenges in our society are multiple, and dealing with them in different spheres requires knowledge of historical processes and human endeavors," highlighting the importance of understanding science and technology in their social and cultural aspects. Simoutaneously, "STL demonstrates its value as a formative perspective, not only for the construction of knowledge, but also for fostering civic participation and social emancipation" (G. Fernandes, 2025, p. 16).

When investigating the potential of STL in the school context, different studies have discussed and analyzed this process from specific dimensions (practical, cultural, and civic), and more recently, from the perspective of the social transformation dimension (G. Fernandes, 2025; Fernandes et al., 2024; I. Fernandes, 2025; Fernandes et al., 2025). In that regard, students are encouraged to discuss, reflect, and act critically, using dialogue, problem-solving, and transformative action as tools to understand and intervene in social structures. This process enables the development of a critical and reflective stance towards social, political, economic, and ethical issues related to science and technology, allowing individuals to understand and transform the reality in which they are embedded. STL and its dimensions thus maintain a close relationship with the different Visions of SL (Sjöström, 2018, 2024; Valladares, 2021), as systematized in Figure 1.

1 STL constitutes a unique construct, but its development takes on distinct forms, depending on the context in which it occurs, and the needs of the actors involved. As highlighted by Auler and Delizoicov (2001), the objectives assigned to STL are multiple and sometimes diffuse: they can range from promoting critical social participation in issues related to science and technology to purposes more aligned with the legitimization and public support of the current dynamics of technoscientific development. Recent studies have broadened this discussion by analyzing STL from different perspectives, both globally and in school contexts (Santos & Silva, 2025; Milaré et al., 2021). From a global perspective, STL can be fostered by public policies or private initiatives that aim, above all, at the critical and conscious civic education, allowing individuals to understand and evaluate the impacts of science and technology on contemporary society (I. Fernandes, 2025). Within the context of Basic Education, known as school-based STL, its development depends on methodologies, approaches, and pedagogical strategies that promote critical thinking, contextualization, and the meaningful appropriation of scientific and technological knowledge, in order to favor the comprehensive education of students (I. Fernandes, 2025).

Figure 1

Relationships between SL conceptions and STL dimensions

SL Visions	Dimensions for the STL (school)	Characterization for the classroom context
Vision I	Vision I: Practical STL	Students seek to understand natural phenomena, processes, and the workings of everyday technologies, using scientific and technological knowledge based on elements of scientific language.
Vision II	Vision IIA: Cultural STL	Understanding the historical and social contexts in which scientific and technological knowledge is embedded, promoting philosophical and sociological reflection and discussion on the nature of science and technology.
	Vision IIB: Civic STL	Students grapple with decisions that involve the application and social contextualization of scientific and technological knowledge. They argue about the socio-scientific and socio-technological aspects and the social context of technological and scientific activity, in relation to the economy, industry, consumption, aesthetic trends, ethics, belief in progress, among others.
Vision III	Vision III: Social Transformation STL	Students discuss, reflect on, and act through dialogue, problematization, and transformative action, focusing on changes in social structures. They demonstrate the ability to understand and act critically and reflectively on social, political, economic, and ethical issues related to science and technology present in their lives and in society, so that their reality can be transformed.

Source: Adapted from G. Fernandes (2025, pp. 12–13).

Establishing a systematic relationship between Vision III of SL (Sjöström, 2018, 2024; Valladares, 2021), and STL (Auler, 2003; Auler & Delizoicov, 2001; Dutra et al., 2017; Fabri, 2020; G. Fernandes, 2025; Fernandes et al., 2024; I. Fernandes, 2025; Fernandes et al., 2025; Fourez, 1997, 2003, 2005; Fumeiro et al., 2019; Lawall, 2021; Lima, 2025; Lorenzetti, 2021; Milaré & Richetti, 2021; Richetti & Milaré, 2021; Rosa & Amaral, 2021), Santos and Silva (2025) proposed expanding the concept of ACT to encompass social transformation. From the STL perspective as social transformation, it promotes emancipation, empowering students to act locally and globally, exercising their social participation consciously and grounded in principles such as social, educational, and economic justice, democracy, citizenship, sustainability, and equality. Furthermore, this training provides students with the tools to recognize ideologies, understand political dynamics, and adopt interdisciplinary perspectives, enabling them to transform society and themselves, as well as act critically in the world.

From this perspective, if STL as social transformation seeks to promote conscious participation, emancipation, and critical engagement among students, it becomes necessary to understand how this process can be constructed within the classroom context. This is where DSKs become relevant, as they allow us to visualize the social process of science and understand how modes of scientific production can be mobilized in Science Education in conjunction with the different dimensions of STL.

Domains of Scientific Knowledge (DSK)

Based on studies in Learning Sciences, Scientific Studies, and Science Education, DSKs allow for visualizing the social process of science in the classroom, creating opportunities for interaction with themes, knowledge, values, practices, and materials that promote learning (Duschl, 2008; Pickering, 1995; Silva & Sasseron, 2025; Stroupe, 2014).

The **conceptual** domain refers to the conceptual structures and cognitive processes used in scientific reasoning, encompassing theories, principles, laws, and ideas that guide research (Duschl, 2003, 2008; Stroupe, 2014). Epistemic domain encompasses "the epistemological frameworks used in developing and evaluating scientific knowledge" (Duschl, 2008, p. 277), allowing students to decide "what they know and why they are convinced they know it" (Stroupe, 2014, p. 492). **Social** domain refers to the "social processes and contexts that shape how knowledge is communicated, represented, argued, and debated" (Duschl, 2008, p. 277) and how students "agree on norms and routines for handling, developing, critiquing, and using ideas" (Stroupe, 2014, p. 492). **Material** domain, on the other hand, refers to the use and adaptation of tools, technologies, inscriptions, and other resources to support the intellectual work of scientific and technological practice (Pickering, 1995; Stroupe, 2014).

Mobilization of DSK (conceptual, epistemic, social, and material) and the dimensions of STL (practical, cultural, civic, and social transformation) present a close relationship with the potential to contribute to Science Education and research in Science Education (Santos & Silva, 2025). This relationship is expressed in the way students mobilize different DSKs, interacting with scientific and technological knowledge and relating them to different STL dimensions (practical, cultural, civic, and social transformation), as can be seen in Figure 2.

Figure 2

Dimensions of STL developed through the mobilization of DSKs

DSK	Definition	Dimensions for STL			
		Characterization for the classroom context			
		Pratical	**Cultural**	**Civic**	**Social transformation**
		Students seek to understand natural phenomena, processes, and the workings of everyday technologies, using scientific and technological knowledge based on elements of scientific language.[2]	Understanding the historical and social contexts in which scientific and technological knowledge is embedded, promoting philosophical and sociological reflection and discussion on the nature of science and technology.[2]	Students grapple with decisions involving the application and social contextualization of scientific and technological knowledge. They argue about the socio-scientific and socio-technological aspects and the social contextualization of technological and scientific activity in relation to the economy, industry, consumption, aesthetic trends, ethics, belief in progress, among others.[2]	Students discuss, reflect on, and act upon changes in social structures through dialogue, problematization, and transformative action. They demonstrate the ability to understand and act critically and reflectively on social, political, economic, and ethical issues related to science and technology present in their lives and in society, so that their reality can be transformed.[2]
Conceptual	Conceptual structures and cognitive processes used in scientific reasoning.[3] How theories, principles, laws, and ideas are used by actors to reason with and about these ideas.[4]	Used to access the conceptual structures, cognitive processes, theories, principles, laws, and ideas used in scientific reasoning and, therefore, in making use of scientific language.	Since scientific theories, principles, laws, and ideas are embedded in historical and social contexts, reflecting on and discussing these concepts from a cultural perspective requires students to contextualize scientific knowledge within its historical and social time, recognizing that scientific theories are shaped by social conditions and the needs of society.	Composing and legitimizing their arguments through theories, principles, laws, and ideas about socio-scientific and socio-technological aspects.	Used to appropriate the theories, principles, laws, and ideas necessary to reason scientifically and technologically about the social, political, economic, and ethical issues of science and technology in order to transform their reality.

2 The authors (2025).
3 Duschl (2008).
4 Stroupe (2014).

Figure 2

Dimensions of STL developed through the mobilization of DSKs (continuation)

DSK	Definition	Dimensions for STL			
		Characterization for the classroom context			
		Pratical	Cultural	Civic	Social transformation
DSK	Definition	To understand natural phenomena, processes, and the workings of technologies using scientific and technological knowledge and scientific language, students access the structure of knowledge, such as data and evidence, to decide what they know and why they are convinced of it.	To reflect on and discuss the philosophy and sociology of the Nature of Science and the Nature of Technology, as they evolved from the interaction between science, technology, and society over time, students use knowledge structures, such as data and evidence, to develop and evaluate their understanding in the classroom.	It is used to enable students to act confidently in decision-making involving the application of social contextualization to scientific knowledge, since this domain allows students to decide what they know and why they are convinced of what they know.	It is used to develop and evaluate scientific and technological knowledge, as this domain is the philosophical basis by which students decide what they know and why they are convinced they know it, and thus they can understand and act critically and reflectively about science and technology to transform their reality.
Social	This refers to the social processes and contexts that shape how knowledge is communicated, represented, argued, and debated.[3] Also, how the actors agree on norms and routines for handling, developing, critiquing, and using ideas.[4]	In seeking to understand natural phenomena, processes, and the workings of technologies, students can encounter forms of representation and communication that aid in the appropriation of scientific and technological knowledge.	By observing the modes of communication and debate surrounding scientific knowledge, students build a foundation for philosophically and sociologically discussing how scientific and technological knowledge is legitimized and disseminated over time.	It is used to negotiate how they communicate their arguments regarding socio-scientific and socio-technological aspects.	The success of students' critical and reflective engagement with social, political, economic, and ethical issues related to science and technology depends on how these students communicate, present, argue, and debate scientific and technological knowledge.
Material	This refers to how actors create, adapt, and use tools, technologies, inscriptions, and other resources to support the intellectual work of the practice.[4]	This is used through the creation, adaptation, and application of tools, technologies, and other resources to support the use of scientific language and the process of understanding natural phenomena, processes, and the functioning of technologies.	This is used by students to create, adapt, and utilize tools, technologies, inscriptions, and other resources to support their discussions, as well as to corroborate their reflections and understandings about the historical and social contexts in which scientific and technological knowledge is embedded.	This is used to create, adapt, and utilize tools, technologies, and registrations both to support their decision-making and to corroborate their arguments.	This is used to foster students' understanding and critical engagement with social, political, economic, and ethical issues related to their ability to create, adapt, and utilize tools, technologies, registration methods, and other resources to argue, negotiate, validate, and legitimize their arguments.
		STL and DSK			

Source: Adapted from Santos and Silva (2025, pp. 12–13).

Based on the proposal by Santos and Silva (2025), different DSKs can be mobilized for each of the dimensions of STL (Figure 2).

STL, as a form of social transformation, can be developed in the classroom context, provided it is guided by a well-structured didactic intention (Fernandes et al., 2024). One way to achieve this would be to adopt an approach permeated by science education as a social practice, enabling students to mobilize different critical thinking skills and, therefore, experience the social nature of science (Duschl, 2008; Longino, 1990; Stroupe, 2014). In that regard, science is understood both as a set of concepts and methods and as a human endeavor, deeply interconnected with social, historical, and cultural dimensions (Silva & Sasseron, 2021; Silva et al., 2022). Highlighting the social character of scientific activity has proven to be a promising way to address contemporary educational and social challenges, such as the discrediting of science and scientists, misinformation, and denialism, which in turn exacerbate environmental impacts and perpetuate social injustice (Silva & Sasseron, 2021).

Then, different dimensions of STL can be developed from the mobilization of different DSKs (I. Fernandes et al., 2025; Santos & Silva, 2025), encouraging the active participation of students in the construction of knowledge and in problematizing the relationships between society, technology, and science, as well as in their actions within their communities (G. Fernandes, 2025; Fernandes et al., 2024; Fernandes et al., 2025; Santos & Silva, 2025; Sasseron, 2024; Silva et al., 2022).

If the different dimensions of STL can be developed from the mobilization of different DSKs, it becomes fundamental to discuss pedagogical approaches capable of guiding this process in the classroom context. Therefore, DSTs are an alternative, since this didactic-social model articulates the learning of scientific and technological knowledge with social problems and the development of STL as social transformation.

Didactic Social Technologies (DST)

Brazilian literature presents different definitions for the concept of Social Technology (ST), which converge on the understanding that it is a socially constructed process, oriented towards solving collective problems. The Institute of Social Technology (ITS[5], 2004) defines social technology as the "set of techniques and transformative methodologies, developed and/or applied in interaction with the population and appropriated by it, which represent solutions for social inclusion and the improvement of living conditions" (p. 26). Along the same lines, Dagnino (2014) understands TS as:

> [...] the result of the action of a collective of producers on a work process that, due to a socioeconomic context (which engenders the collective ownership of the means of production) and a social agreement (which legitimizes associativism), which give rise, in the production environment, to a (self-management) control and a cooperation (of a voluntary and participatory nature), allows for a modification to the generated product that can be included according to the collective's decision (p. 144).

5 Translation note: Brazilian Portuguese acronym to be correspondent to the final reference list.

Within the school context, however, the notion of Social Technology still lacks a more precise conceptual definition, often being reduced to specific projects or teaching resources, without considering its procedural nature (I. Fernandes, 2025). Given this gap, Fernandes et al. (2024) and I. Fernandes (2025) proposed that Social Technologies can be developed in the school environment through Didactic Social Technologies (DST). Although DSTs have their conceptual origin in the propositions of TS formulated by Dagnino (2010, 2014), they diverge in specific aspects (I. Fernandes, 2025).

From this perspective, DST broadens the scope of TS by considering the school community as a specific social group not explicitly covered by Dagnino (2010, 2014). While the discussion by Dagnino (2010, 2014) is based on the concepts of Sociotechnical Adequacy[6] (STA) and of Solidarity Economy (SE)[7]. I. Fernandes (2025) proposes, for the school context, the concept of **Socio-technical Pedagogical Mediations (STPM)**, as illustrated in Figure 3. Then, when implementing and developing ST in the school environment, what is carried out is not a Socio-technical Adaptation in the mold of Dagnino (2010, 2014), but an STPM adapted to the pedagogical, curricular, and formative specificities of the school community. In that regard, Figure 3, adapted from the studies of Fernandes et al. (2024), schematically presents the transition from Sociotechnical Adequacy, a characteristic of Conventional Technology[8] (CT) for Social Technology (ST), as discussed by Dagnino (2010, 2014), and through a process of STPM, the transposition of (Community-Based) ST (Didactic) ST in the school context.

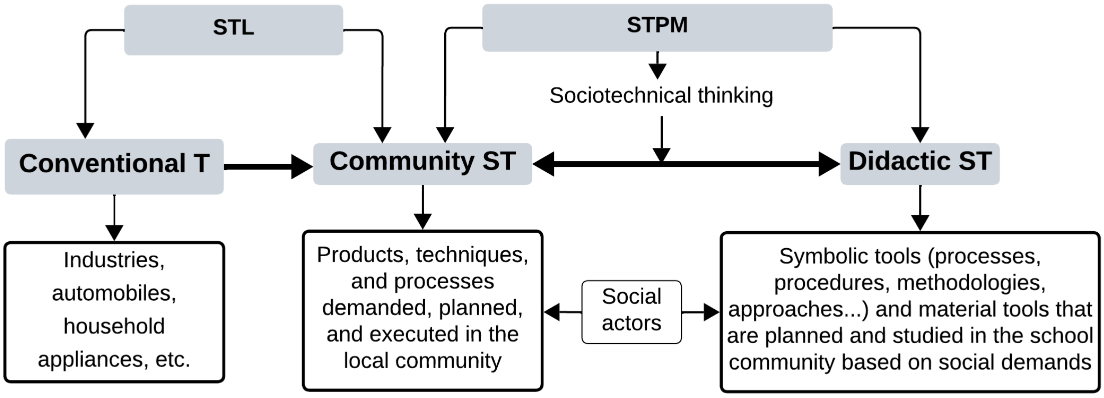
6 STL aims to adapt the TS and devise alternatives, incorporating supplementary criteria to conventional technical-economic ones. These supplementary criteria are applied to the production and circulation of goods and services in non-formal circuits, located in rural and urban areas, aiming to optimize their impacts and promote greater social and economic effectiveness (Dagnino, 2014; Dagnino et al., 2004).

7 According to Dagnino (2010, 2014), SE is defined as a set of organizations and enterprises (cooperatives, associations, recovered factories, etc.) characterized by collective ownership of the means of production and self-management, in which management and the allocation of results are decided democratically and participatively by the workers. For the author, SE should not be seen merely as a survival mechanism or "odd job" for the poor; it should also be seen as a new civilizational proposal and as an alternative mode of production to capitalism.

8 CT can be understood as a set of large-scale production systems and processes that are "intensive in capital, technical knowledge, and resources" (Souza & Pozzebon, 2020, p. 234), and are characterized, among other aspects, by their negative impact on the environmental, social, ethical, and political spheres. According to Rios and Lima (2016, p. 95), "conventional technology is well known, even represented in discussions by structural unemployment", because its production pace, dictated by machines, prevents "direct worker control" and restricts the full use of their creative capacity. STs are "increasingly efficient for the purposes of maximizing private profit" (Dagnino, 2014, p. 19), and at the same time, they are segmented and monopolized by large companies, "leading to inequalities" (Rios & Lima, 2016, p. 95), by favoring capital accumulation in rich countries and promoting unequal development among economies.

Figure 3

Articulation between Social Technology (ST) and Didactic Social Technology (DST) through Socio-technical Pedagogical Mediation (STPM)



Source: Adapted from I. Fernandes (2025, p. 49).

To I. Fernandes (2025), the integration of Social Technologies in the school context occurs through STPM, and not through STL. In this process, DST takes on educational purposes geared towards STL, linking the learning of scientific and technological knowledge to social issues and promoting dialogue with the community, valuing local knowledge, and fostering social transformation.

DSTs are characterized as a didactic-social model[9] with the potential to develop different dimensions of STL (Fernandes et al., 2025). DST offers opportunities to develop STL as a means of social transformation, fostering discussions, reflections, and actions among students on scientific, technological, political, economic, and environmental aspects (Fernandes et al., 2024). Furthermore, it enables students to plan, outline, study concepts, develop projects, and analyze the social impacts of science and technology (Fernandes et al., 2025). Still, according to Fernandes et al. (2025), this process begins in the school and expands to the community, mobilizing different social actors (Archanjo & Gehlen, 2021) when proposing the development of an ST. In that regard, the concept of DST is based on transforming the students' environment, encouraging their active participation in creating DST in their communities (G. Fernandes, 2025).

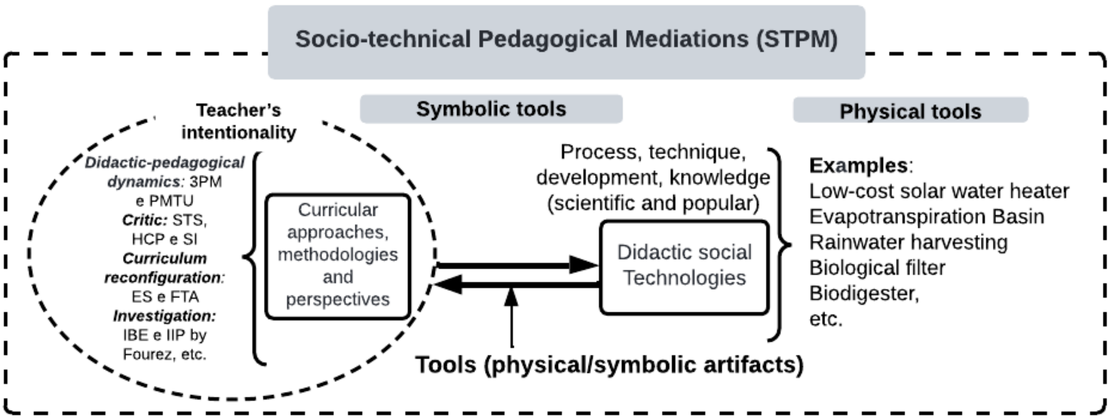
DST development requires the active mediation of the teacher, who plays a fundamental role in the process. According to Fernandes et al. (2024), the teacher acts as a mediator and social actor, leading activities and promoting interaction between different social actors with diverse knowledge.

9 DTS It is understood as a didactic-social model that articulates process and product in response to a social problem, starting from the development and reflection on a social demand until its materialization in a final product, called "Didactic Social Technologies" (I. Fernandes, 2025). This didactic-social model allows for debate on social, political, economic, and ethical issues, representing an important possibility for science education (Fernandes et al., 2024; I. Fernandes, 2025).

This teacher mediation implies, in addition to understanding DST as a didactic-social model, also understanding the STPM, which enables its development in the school context. For I. Fernandes (2025), MSTPs enable TSD through the articulation between **symbolic tools**[10] and **physical tools**, as illustrated in Figure 4. From this perspective, for the author, DST, as a symbolic tool, expresses the teacher's intentionality in the choice and articulation of curricular approaches, methodologies, and perspectives; as physical tool, DST materializes as a pedagogical product, resulting from the educational process developed.

Figure 4

Socio-technical Pedagogical Mediations and the articulation between Symbolic and Physical Tools in the development of DST



Source: I. Fernandes (2025, p. 71).

Several examples of educational practices illustrate the teaching intentionality. Fernandes et al. (2022) describe teaching intentions linked to three Pedagogical Moments (3PM) and to Potentially Meaningful Teaching Units (PMTU), these latter are based on Critical Meaningful Learning (Fernandes et al., 2024). The authors also point to critical practices, such as the Science-Technology-Society (STS) approach, Historical-Critical Pedagogy (HCP) and Socioscientific Issues (SI). When the teacher's intentionality involves curricular reconfiguration, Fernandes et al. (2024) highlight the Study Situation (SS) and the Freirean Thematic Approach (FTA). From an investigative perspective, Inquiry-Based Science Education (IBSE) stands out, Also the Scientific Case Studies and the Interdisciplinary Island of Rationality (IIR) (Fourez, 2005). It is important to highlight that teacher autonomy permeates this entire process: it is up to the teacher to adopt, adapt, or transform such educational practices according to the demands of the students, the community, and the social context.

Another aspect to be considered refers to the integration of different curricular components with social themes, which can be favored through DST. Fernandes et al. (2024) point out that incorporating social themes into the study and development

10 The concept of a tool is based on Engeström's Activity Theory (1987), inspired by Vygotsky (1978).

of DST can be relevant for building a multi-, pluri-, or interdisciplinary curricular perspective, encompassing content from Science, Biology, Geography, Sociology, History, Mathematics, Physics, and Chemistry, and contributing to STL as a social transformation (G. Fernandes, 2025; Fernandes et al., 2024). However, Fernandes et al. (2025) warn that DSTs should not be confused with project-based learning, experimental resources, or the STEM (Science, Technology, Engineering, and Mathematics) approach, differing instead in their commitment to social transformation and the mobilization of social actors.

Therefore, understood as a didactic-social model, articulated with the MSTP (Modern Social and Political Technology) and the movement between the symbolic tool and the physical tool (I. Fernandes, 2025), DST presents itself as a promising path for the development of the different dimensions of STL (Fernandes et al., 2024). By integrating the learning of scientific and technological concepts with issues of a scientific, technological, political, economic, and environmental nature, DST fosters the development of educational practices grounded in the reality of students and their communities. This potential, however, depends directly on a clear and structured teaching intention, capable of guiding pedagogical practices towards the mobilization of critical thinking skills and the promotion of a critical, reflective, and socially committed education.

Based on this understanding of DST as a didactic-social model, articulated with STPM, symbolic tools, and physical tools, it becomes possible to move forward with an analysis of its contributions to the development of the dimensions of STL and the mobilization of DSK. More than characterizing DST, we are interested in understanding how its theoretical and methodological propositions, guided by teacher intentionality, can favor new forms of articulation between STL, DSK, and DST in Science Education.

Contributions of DSTs to the Mobilization of DSKs and the Development of STL Dimensions

I. Fernandes (2025) presents a theoretical and methodological proposal (Figure 4) for the development of DSTs. For this development to occur, the teacher plays a central role, using their pedagogical intentionality to mobilize a broad repertoire of practices, articulating with the DST and potentially being supported by other social actors, especially those in the school community (Fernandes et al., 2024).

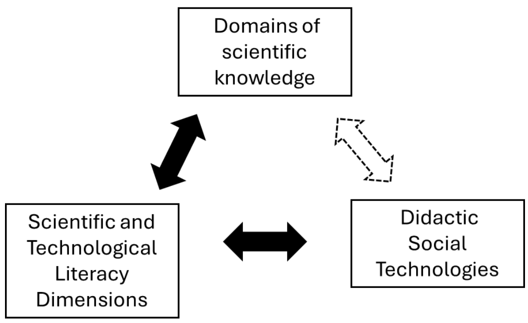
Although Fernandes et al. (2024, p. 4) propose that "STL as social transformation can be developed through science education as a social practice (Silva & Sasseron, 2021; Silva et al., 2022) around scientific, technological and social problems", the authors do not explain how this proposal articulates with the DSK. Literature in the field (Silva & Sasseron, 2021; Silva et al., 2022) understand science education as a social practice to be characterized by the mobilization of DSK in the classroom through scientific practices such as argumentation, investigation, and modeling.

However, it is important to highlight that, historically, the mobilization of DSKs has occurred predominantly in the context of approaches such as inquiry-based science teaching, whose development also depends on the teacher's intentionality. In this study, we broaden this perspective by arguing that DSKs can also be mobilized based on the teacher's intentionality and the development of DST, which allows for new forms of articulation with different educational practices and fosters a more critical and socially engaged scientific and technological education. Expanding our discussion on teacher intentionality for the mobilization of DSKs but using software in an educational context as an example, Sena et al. (2025) argue that the formative potential lies not in the artifacts themselves, but in how they are pedagogically used by the teacher.

Expanding this perspective becomes even more relevant when we consider that the literature in the field (Santos & Silva, 2025) already shows consistent relationships between the mobilization of DSKs and the development STL dimensions. Meanwhile, recent studies (G. Fernandes, 2025; Fernandes et al., 2024; I. Fernandes, 2025) demonstrate that the different STL dimensions can be effectively developed through DST. Then, by establishing connections between DSK and DST (Figure 5), this study contributes to the contemporary debate in Science Education, offering theoretical and methodological support that responds both to the current demands of Science Education and to the broader social challenges that permeate the educational context.

Figure 5

Articulation between the mobilization of DSKs and DSTs for the development of STL dimensions



Source: Prepared by the authors.

From Figure 5, it is possible to identify the articulations between the DSK and the STL dimensions (Santos & Silva, 2025), as well as between the STL dimensions and DST (G. Fernandes, 2025; Fernandes et al., 2024; I. Fernandes, 2025) are already well-established in the literature through theoretical foundations, and in the case of STL and DST, also through empirical evidence (Fernandes et al., 2025). In that regard, a gap stands out regarding the direct links between DSKs and DSTs, represented in Figure 5 by the double empty and dashed arrow, the investigation of which still requires further research. Then, this study aims to explore this relationship, contributing to the advancement of discussions in the field of Science Education and broadening the understanding of how DSTs can promote the mobilization of different DSKs.

Based on the proposition of linking the STL dimensions with the DSKs, we understand that the teacher's intentionality constitutes the central element or catalyst for mobilizing the domains within the DST context. When we revisit the concept of symbolic tool (I. Fernandes, 2025) that is understood as the expression of the teacher's intentionality in the choice and articulation of curricular approaches, methodologies, and perspectives, it becomes evident that this moment demands careful pedagogical attention from the teacher. Silva and Sasseron (2025) argue that when students receive overly structured lesson plans, with predefined steps and predetermined materials, the emergence of the epistemic, material, and social domains becomes unlikely.

According to Silva and Sasseron (2025), the abundance of information and readily available resources tends to suppress opportunities for interaction among students, limiting their possibilities for analysis, decision-making, and negotiation on how to achieve the proposed objectives. Furthermore, the direct application of scientific concepts compromises their relevance (epistemic domain) and weakens the social domain by inhibiting the collective negotiation of criteria, methods, and forms of communication. Then, the teacher's intentionality, materialized in the symbolic tool, is crucial for creating conditions that favor the coordinated mobilization of the different DSKs in DSTs development.

Stroupe (2014) argues that, to make Ambitious Science Education viable[11], it is necessary for the teacher to have a broad and diverse repertoire of pedagogical practices. In that regard, the model of "Dimensions of STL developed through the mobilization of DSKs" (Figure 2) assumes that the development of TSD should be supported by different educational practices, selected and articulated according to the teacher's intention.

However, for the mobilization of DSKs to materialize based on the teacher's intention in developing DSTs, it is essential that the teacher values and prioritizes dialogic processes among students. The centrality of dialogic processes in the classroom, combined with the promotion of active student participation, constitutes an essential pedagogical condition for the coordinated mobilization of the different DSKs (Sena et al., 2025). Then, the incorporation of dialogical processes through investigation[12] in the classroom encourages the social practice of science among students, allowing them to understand how knowledge is constructed, evaluated, and legitimized (Duschl, 2008; Silva & Sasseron, 2025).

11 Stroupe (2014) calls "ambitious science teaching" a teaching approach in which the teacher ceases to be merely a transmitter of content and begins to organize the class so that all students legitimately participate in the disciplinary work, learning science as a practice. This implies welcoming and working, over time, with students' ideas as central resources in the classroom, redistributing cognitive authority within the class, and creating routines in which students act as epistemic agents, that is, they should be responsible for formulating, testing, justifying, and revising explanations and models that enable the mobilization of the conceptual, epistemic, social, and material domains.

12 Recent literature indicates that, although there is no consensual and unequivocal definition of what characterizes Inquiry-Based Science Education, there is a shared understanding that this didactic approach has as its central focus the resolution of a research question through the engagement of students in practices characteristic of science, which can occur through the adoption of **various teaching strategies** (Vechiato & Scarpa, 2024). In that regard, we understand that, based on a clearly defined teaching intention, it is possible to incorporate investigative approaches into the development of Didactic Social Technologies, expanding the possibilities for mobilizing DSKs.

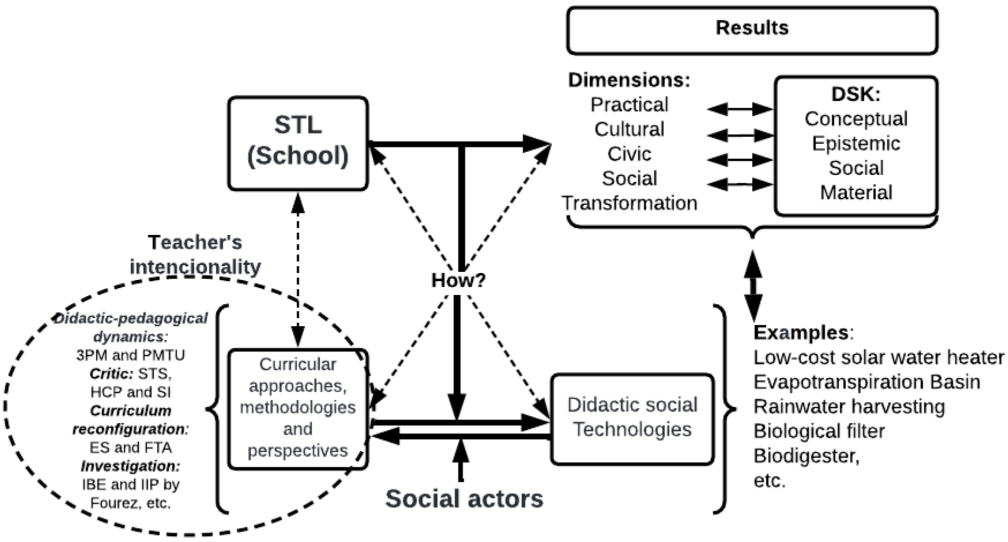
According to Stroupe (2014), dialogical processes are how DSKs can be effectively mobilized. Firstly, because dialogical processes enable the attribution of epistemic agency[13] to students, allowing them to learn Science as a practice, that is, as a collective, situated, and public endeavor. Sharing epistemic agency implies recognizing that the teacher is not the sole cognitive authority in the classroom, legitimizing student contributions as part of the knowledge production process.

Secondly, by fostering dialogical processes, the teacher creates an environment in which discursive movements attribute value to the scientific ideas presented by the students, characterizing science as a public practice, and not as private knowledge restricted to the figure of the teacher. Then, dialogical processes become indispensable components for DSKs to be mobilized in an integrated and coherent way within the context of DSTs.

From this perspective, as illustrated in Figure 6, DSKs can be mobilized in the process of developing STL dimensions (Santos & Silva, 2025), and still within the scope of DST, based on an explicit and structured teaching intention, according to the theoretical-methodological proposition of DST.

Figure 6

Mobilizing the Domains of Scientific Knowledge in the development of STL dimensions and Didactic Social Technologies based on teacher intentionality



Source: Adapted from Fernandes et al. (2024, p. 11).

Figure 6 shows that, from the development of DST, multiple opportunities arise for the mobilization of DSKs, both in the context of the development of the different dimensions of STL and as a function of an explicit and structured teaching intention.

13 This refers to the capacity and responsibility that individuals or groups assume, or are assigned, to influence and shape knowledge and practices within the community of scientific practice (Stroupe, 2014).

Then, the figure of the teacher, expressed through their intentions, and therefore through the symbolic tool of STPM, their repertoire of pedagogical practices, and their openness to dialogue and dialogical processes, becomes fundamental for the DSKs to be mobilized during the STPM of DST. This perspective broadens the potential of DSKs, which cease to be restricted to investigative practices and begin to contribute to different pedagogical purposes, promoting a critical and socially oriented scientific and technological education[14].

Although the articulation between DST, DSK, and STL dimensions reveals relevant possibilities for Science Education and for a critical and socially oriented scientific and technological education, its realization does not occur automatically. Conversely, this mobilization depends on specific pedagogical and formative conditions, among which teacher training stands out, an aspect that needs to be problematized to understand the limits of the development of DST in the school context.

The Limits of DSK Mobilization Based on DST Development

Duschl (2008) and later Stroupe (2014) constitute the main theoretical frameworks for understanding DSK. In Brazil, DSKs have not yet been fully incorporated into teacher training, suggesting that few teachers intentionally and systematically utilize these domains in their pedagogical practices.

A similar scenario occurs with regard to DSTs, which, despite the advancement of studies on Social Technologies in school contexts (Archanjo & Gehlen, 2022; Archanjo & Gehlen, 2021; G. Fernandes, 2025; Barbosa et al., 2024; Fernandes et al., 2025; Lemes et al., 2023), remain in the initial phase of theoretical foundation, empirical investigation, and educational implementation.

Specifically regarding DSKs, van Uum, et al., (2021) highlight the need for future research to focus on initial teacher training, indicating that both formal and non-formal settings can play this role. In agreement, Lau and Sikorski (2018) highlight the potential of science museums as relevant environments for teacher professional development.

Silva et al. (2022) emphasize that adopting new teaching approaches requires structured planning, qualified teacher mediation, and systematic reflection on dialogical processes. These elements make initial and ongoing training inseparable in the development of innovative practices. According to the authors, training courses should offer opportunities for interns to plan, implement, and evaluate lessons grounded in the conception of science as a social practice, involving epistemic concepts, tools, norms, and procedures.

14 We understand a socially oriented scientific education, as well as Tenreiro-Vieira and Vieira (2013, p. 184). When discussing socially oriented goals, the authors contrast them with a scientific education that is "exclusively preparatory," focused solely on "the pursuit of scientific studies and careers." From this perspective, for the authors, science and mathematics education should form citizens who recognize "science and mathematics as human endeavors that are an integral part of culture, are able to mobilize knowledge in daily life and work, and intervene socially, in a critical way, in decision-making."

In this same vein, Subramaniam (2023) argues that teacher training curricula need to be reformulated so that future teachers experience in-depth and contextualized investigations into the construction of scientific knowledge, linking them to scientific practices and developing a critical professional vision.

Finally, Sasseron et al. (2025) exemplify and problematize the fragility of CNE/CP Resolution N. 02/2019, which sought to establish teacher training guided by the competencies of the National Common Curricular Base (BNCC—Portuguese acronym). The problem is that the competencies outlined in the BNCC don't always explicitly present science as a social practice. For instance, according to Article 2 of the document (Resolution, 2019), the undergraduate's education should ensure the development of general competencies and essential learning outcomes in Basic Education. However, when these "essential skills and learning, embodied in the abilities analyzed here, fail to address science as a social practice" (Sasseron et al., 2025, p. 24), the teachers' education is capable of articulately mobilizing the DSKs in the classroom, highlighting important limitations in the current normative frameworks of teacher training.

Thus, mobilization of DSKs depends directly on the initial and ongoing training of science teachers, and this dependence becomes even more evident when articulated with the need for teacher intentionality in the development of DSTs. Teachers' education, therefore, is a decisive element for the success of these proposals. Such training can occur in formal and non-formal spaces, including mandatory curricular internships and/or the Institutional Scholarship Program for Teaching Initiation (PIBID in its Portuguese acronym), which promote the confrontation between theory and practice, university extension activities, and continuing education programs focused on curricular reorganization, critical content planning, and the development of investigative practices, among other formative perspectives.

Conclusion

The development of STL dimensions, especially the social transformation dimension, has been understood in the literature (G. Fernandes, 2025; Fernandes et al., 2024; I. Fernandes, 2025; Fernandes et al., 2025; Lima, 2025) as a theoretical construct capable of contributing to addressing contemporary social problems through science and technology. These problems are complex, multifaceted, and marked by political, economic, and cultural disputes. Given this scenario, authors (Silva & Sasseron, 2021; Silva et al., 2022) have argued for the importance of students' understanding the social nature of scientific activity, which is only possible when science education is guided by teacher intentionality and conceived as a social practice. This perspective opens up space for the mobilization of different DSKs.

Considering this complexity, we understand that addressing contemporary social problems requires the articulation of multiple educational practices. Within this context, DSTs, as a didactic-social model, constitute a promising proposal for integrating science, technology, and social action. DSTs show potential to foster the resolution of real problems when developed in a way that is articulated with the mobilization of DSKs.

Santos and Silva (2025) demonstrate that DSKs can be mobilized throughout the development of the different STL dimensions. In this work, we advance this discussion by highlighting how DSKs can be mobilized within the theoretical-methodological proposition of DST, which also includes STL dimensions. The proposal presented here seeks to broaden the ways in which DSKs can mobilize, situating them within the context of educational practices committed to a critical and transformative conception of STL.

In that regard, we argue that the educational practices planned according to the theoretical-methodological proposition of DST (I. Fernandes, 2025) constitute a fertile environment for the mobilization of different domains: conceptual, epistemic, social, and material. This favors scientific and technological training oriented towards social transformation.

However, we emphasize that the mobilization of DSKs, when linked to the development of DSTs and the dimensions of school STL, depends directly on the teachers' intentionality. Then, Initial and continuing education teachers constitute one of the main challenges for the consolidation of this proposal. Only through robust training processes that support teachers in expanding their pedagogical and epistemological repertoire will it be possible to implement practices that consistently articulate DST, DSK, and STL in the classroom.

As a contribution, this study proposes conceptual advancement by aligning STL with a more consolidated theoretical movement in the field of Scientific Literacy (SL), especially in its articulation with DSK. In doing so, we seek to contribute to the understanding of STL, also considering a contemporary perspective of science, understood as a social practice and as a process marked by different modes of knowledge production. Furthermore, we argue that the notion of DST broadens the discussion on Social Technology by shifting it to the didactic field, considering the school and the school community as formative spaces in which teacher intentionality, science education, and commitment to social transformation are articulated.

In that regard, the main innovation of the study lies in the articulation between STL, DSK, and DST, since this proposition allows us to understand how the development of different STL dimensions, such as critical, civic, cultural, and social transformation, can occur in teaching contexts that favor the mobilization of conceptual, epistemic, social, and material domains, while promoting the understanding of science as a social practice and the problematization of social, political, economic, and ethical issues related to science and technology.

Authors' Contribution

Conceptualization: Santos, D. L., Fernandes, G. W. R., Silva, F. C.; **Data curation:** Santos, D. L.; **Formal analysis:** Santos, D. L., Fernandes, G. W. R., Silva, F. C.; **Investigation:** Santos, D. L.; **Methodology:** Santos, D. L.; **Project administration:** Santos, D. L., Silva, F. C.; **Resources:** Santos, D. L.; **Software:** Santos, D. L.; **Supervision:** Silva, F. C.; **Validation:** Fernandes, G. W. R., Silva, F. C.; **Visualization:** Fernandes, G. W. R., Silva, F. C.; **Writing – original draft:** Santos, D. L.; **Writing – review & editing:** Santos, D. L., Fernandes, G. W. R., Silva, F. C.

Data Availability Statement

All dataset were generated or analyzed in the current study.

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