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Research Issues Orbiting the STS Approach: A Network Analysis of the Brazilian Academic Production in Education

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Science-Technology-Society (STS) is an approach that recognizes science and technology as complex social processes and that is established at the confluence of several search fields. This article aims to identify which research themes are related to STS in the Brazilian academic production. Therefore, as a methodological tool, we opted for using the Network Analysis on the keywords of 144 articles published in journals of the field. When viewing the network, the generated image resembled an orbital, showing STS in the center and the other 173 keywords around it. Based on the network centrality measures, we identify the twenty most relevant keywords, which composed a set of research themes connected to STS. The qualitative analysis of this set generated a review of the Brazilian production in STS Education.

Keywords: Science-Technology-Society (STS); Network Analysis; orbital of keywords; Education journals; STS Brazil.

Introduction

The area nowadays called Science-Technology-Society (STS) does not have a single origin, being the result of several studies and interdisciplinary movements over the last decades. Examples of STS developments are the questioning sociopolitical movements of the indiscriminate use of technology and the philosophical, sociological, and historical studies of science and technology.

According to Cutcliffe (2003):

> The central mission of the [academic] STS field, up to now, has been to express the interpretation of science and technology as a social process. From this point of view, science and technology are seen as complex projects in which cultural, political and economic values help us to configure the technoscientific processes that, in turn, affect the same values and the society that holds them. (CUTCLIFFE, 2003 p. 18, our

translation)

This interpretation provides a STS approach to a variety of fields, such as anthropology of science, philosophy of technology, science and technology policy, and education. For a better understanding, Cutcliffe (2003) divides the STS area into three biases: programs focused on Public Policies; Science and Technology Study Programs; and STS programs themselves.

Programs aimed at Public Policies "emphasize the need for, and the preparation for adequate action and management policy studies" (CUTCLIFFE, 2003, p. 107, our translation). Cutcliffe (2003) claims that this trend emerged in the 1960's and 1970's mainly from the concern of engineers and technology managers with a broader sociotechnical context. For González García et al. (1996) this bias is more centered on a North-American tradition, stimulated particularly by some counterculture social movements, with an emphasis on ecology and pacifism.

In Latin America this approach, presented by Dagnino et al. (1996), is called Latin American Thinking in Science-Technology-Society (LATSTS), as the result of a set of ideas of researchers concerned with scientific and technological policy in the region. LATSTS' design encouraged local knowledge production to combat a decontextualized imposition of imported knowledge (SILVA, 2015).

Science and Technology Studies (STS) have emerged from debates "among historians, sociologists and philosophers regarding the inadequacies of internalist explanations about the nature, origin, development and financing of science and technology" (CUTCLIFFE, 2003, p. 111, our translation). González García et al. (1996) highlight the Strong Programme, with Barry Barnes, David Bloor and Steven Shapin, as a milestone in these studies, influenced by a more European tradition and the quest for a "science of science".

This program interprets the production of scientific and technological knowledge as a social process, while the STS seek a more theoretical discussion. This differentiation of Public Policy Programs has made Fuller (1997) denominate "Higher Church" the Studies on Science and Technology, and "Low Church" the movements concerned with Public Policies, due to their more practical character.

Cutcliffe (2003) calls STS itself a strand that emerged in the late 1960's and, in its origin, is related to the necessary changes in higher education.

> These courses and programs place special emphasis on general education for a responsible and intelligent citizenship in a highly scientific and technological society. Thus, they can insist on scientific/technical literacy for a practical citizenship and/or a contextual analysis of science and technology as an end in itself. (CUTCLIFFE, 2003, p. 116, our translation)

As can be seen, the STS education ended up achieving scientific and technological education at all levels of schooling, because no matter the name given, it has led to a culture capable of "changing the status quo by humanizing the science curriculum, so that it would have relevance for the majority of the students" (AIKENHEAD, 2005, p. 114, our translation).

In Brazil, the STS approach focused mainly on research in the educational field, especially on subjects related to science education (ARAUJO, 2009). This fact justifies the choice of Education as our research focus, in order to contribute with a better understanding of how the STS area has been built.

This work aims to identify which research themes are related to the STS area as research focus on Education in Brazil. For this purpose, we glimpse the area as follows: STS would be in the focus of our research and other topics would appear in its surroundings according to its connection with STS. In addition, the stronger the connection, the closer to our core focus the topic would be.

This text is divided into three parts: the first one is a review on the STS approach, its possible origins and conceptualizations; in the second part, we bring the Network Analysis as the methodology chosen to generate a result that would correspond to our goal; and the third part is a qualitative analysis of the production in STS area in Brazil, aiming to stablish the connection between the STS approach and the main themes that orbit it.

Methodology

In order to evaluate which themes are related to STS in national surveys, we have consulted the electronic editions of 26 journals indexed by the Qualis of Education area (triennium 2011-2013). They are: Alexandria - Revista de Educação em Ciência e Tecnologia; Avaliação - Revista da Avaliação da Educação Superior; Biodiversidade; BOLEMA; Caderno Brasileiro de Ensino de Física; Ciência & Cognição; Ciência & Educação; Ciência e Ensino; Ciência em Tela; Educação & Realidade; Educação Matemática Pesquisa; Educar em Revista; Ensaio - Pesquisa em educação em ciências; Experiências em Ensino de Ciências; Investigações em Ensino de Ciências; Pesquisa em Educação Ambiental; Química Nova; Química Nova na Escola; Revista Brasileira de Ciência, Tecnologia e Sociedade; Revista Brasileira de Ensino de Física; Revista Brasileira de Pesquisa em Educação em Ciência; Revista de Ensino de Ciências e Engenharia; Revista de Ensino de Ciências e Matemática – RENCIMA; Revista de Ensino de Engenharia; Revista Iberoamericana de Ciencia, Tecnología y Sociedad; and Tecnologia e Sociedade.

In these journals, we searched for the words 'science', 'technology' and 'society', together or separately. Then we obtained a total of 144 articles published between the years of 1996 and 2014. Based on this set, a question has arisen: if STS was a center of a connected network, what research topics would be orbiting around it? In the search for a plausible answer, we chose to use Network Analysis to generate a possible modeling of the reality of the area.

When thinking of a networked model, "Relationships indicate a connection between two or more people or things [...] [which] can cover the sharing, delivery, or exchange of a wide variety of resources" (HAYTHORNTHWAITE, 1996, p. 326, our translation). And, "one of the major goals in studying how things connect to each other is to understand how this connectivity influences the functionality and processes related to these things" (FIGUEREDO, 2011, p. 345). In this case, we have covered a network formed by the keywords in the articles of our research corpus to find out which research themes have more centrality in a network where STS is the core.

We chose to do this analysis from keywords, once they comprehensively represent the thematic areas of the articles. We extracted the keywords of 137 articles for a spreadsheet, since 7 of the articles selected did not show them. In order to stratify such heterogeneous data, we have created some equivalences, for instance, turning the keyword "STS approach" into the keyword "STS", as well as generalizations, such as including "textbook" as "didactic material" .

Every network is formed by vertices (or nodes) and by connections that can be called edges or arcs, if there is a directed connection between the nodes. Our network has as vertices the keywords and, as edges, the fact that they are linked, because they belong to the same article. In order to elucidate, let's take as an example three articles, which contain the following keywords: teachers' education, STS approach, PIBID and water quality (SILVA; MORTIMER, 2012); simulated cases, STS and teachers' education (XAVIER; FLOR; REZENDE, 2013); STS, curriculum and greenhouse effect (TOMMASIELLO, 2012). After equivalence, the subnet formed was represented by Figure 1.

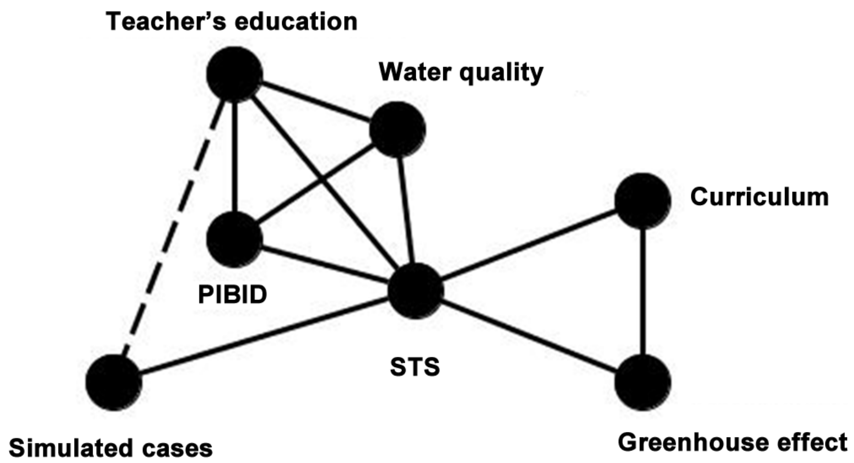

Figure 1. An example of a subnet formed by the keywords

Thus, Figure 1 shows how the network is composed through the connections found between the vertices and the edges. After generating the keyword network of all articles, the graphic corresponding to it contained 199 vertices and 651 edges. As not all keywords were interconnected, we extracted the largest connected component of that network, consisting of 174 vertices and 623 edges, in which the STS theme was present.

The next step was to define the main themes, what we did with the establishment of criteria that pointed to the most central keywords. Although there is no consensus on the definition of centrality of a network, such measures have been used since at least the mid-twentieth century (FREEMAN, 1979). Centrality is one of the most studied concepts in social network analysis.

According to Borgatti (2005), several measures were developed, including degree centrality, closeness centrality, betweenness centrality, eigenvector centrality, information centrality, flow betweenness centrality, among others. Centrality is, as its name suggests, a mathematical way of finding the most central point of a network. In order to avoid biased results due to specific criteria, we adopted three measures of centrality that, used together, avoid discrepancies and lead to more reliable information. They are: closeness, betweenness and eigenvector.

In the measure of closeness centrality, "The larger the closeness centrality of a vertex, the shorter the average distance from the vertex to any other vertex" (OKAMOTO; CHEN; LI, 2008, p. 187). This means that the closer a vertex is to all the other vertices, the information can reach them more easily. In the measure of betweenness, the criterion is the number of connections between different sub-networks that a vertex is able to do.

Vertices with a centrality of high betweenness act as points of control of communication between them, i.e., "Betweenness is a relational measure" (LEYDESDORFF, 2007, p. 1305). In turn, the eigenvector centrality of a vertex is influenced by the importance of its neighbor vertices in the network, that is, even if a vertex has few connections in the network, it can be considered a central vertex if it has links with important vertices (BONACICH, 1987).

Like any research, we need to make a cut in our sample. In search of accuracy, in order to include a keyword to our scope of analysis, we define as a parameter the fact that the word has the centrality measures of closeness, betweenness and eigenvector among the 30 highest values of each of these centralities.

Thus, we united the three measures of importance to verify how these keywords are made up in the large STS teaching network, by considering how much they occupy central positions, how much they connect with other keywords of the same subject and how much they interact with their peers, in order to relate more closely or more distally to the STS core.

Results

In Table 1, we list the keywords that met the criterion of being among the 30 highest values of closeness centrality, betweenness centrality and eigenvector centrality of our network, as well as their positions in the ranking, from highest to lowest value of each of the centralities[1].

1 In our research, we used Pajek software. In it, the algorithms that calculate the three measures of centrality are implemented and can be accessed in the menu commands Network → Create Vector → Centrality. In Batagelj and Mrvar (2002), there are mathematical details of the algorithms and how they were implemented in Pajek.

Table 1. Keywords and their centralities

Keyword	Closeness centrality		Betweenness centrality		Eigenvector centrality	
	Value	Rank	Value	Rank	Value	Rank
STS	0.7621	1st	0.8075	1st	0.6692	1st
Chemistry education	0.4792	12th	0.0072	21rd	0.0585	26th
Citizenship	0.4943	10th	0.0229	12th	0.0781	20th
Contextualization	0.5014	4th	0.0094	17th	0.0682	23rd
Controversy	0.4626	19th	0.0054	22nd	0.0811	18th
Curriculum	0.4943	9th	0.0354	8th	0.1350	6th
Controvérsia	0.4626	19th	0.0054	22nd	0.0811	18th
Didactic material	0.4957	8th	0.0649	4th	0.1131	8th
Education	0.4701	15th	0.0314	10th	0.1017	10th
Environment	0.4915	11th	0.0087	18th	0.0873	16th
Paulo Freire	0.4589	23rd	0.0040	24th	0.0873	15th
Pedagogical practice	0.4753	13th	0.0028	28th	0.0928	12th
Physics education	0.5000	6th	0.0678	3rd	0.0913	13th
Professional education	0.4565	28th	0.0078	20th	0.1149	7th
Science education	0.5274	2nd	0.0511	6th	0.3589	2nd
Scientific and technological education	0.5029	3rd	0.0695	2nd	0.2514	3rd
Scientific and technological literacy	0.5014	5th	0.0644	5th	0.2086	5th
Scientific journal	0.4714	14th	0.0029	27th	0.0625	25th
Socio-scientific issues	0.4577	25th	0.0021	29th	0.0978	11th
Teachers' education	0.4986	7th	0.0368	7th	0.2170	4th
Technology	0.4577	24th	0.0050	23rd	0.0584	27th
Thematic Approach	0.4626	18th	0.0036	25th	0.0750	22nd

When calculating the arithmetic average of the ranking of the three centrality measures each theme presents in table 1, we have as a result a number that reflects the centrality position of the theme. The smaller the number, the closer to STS (which is our 'core'). With this, it is possible to list the themes with stronger links to STS, as follows: scientific and technological education (2.67); science education (3,33); scientific and technological literacy (5.00); teachers' education (6.0); didactic material (6.67); physics education (7.33); curriculum (7,67); education (11,67); citizenship (14.00); contextualization (14,67); environment (15.00); pedagogical practice (17,67); professional education (18,33); controversy (19,67); chemistry education (19,67); Paulo Freire (20,67); thematic approach (21,67); socio-scientific issues (21,67); scientific journal (22,00); and technology (24,67).

Our research offers a glimpse of the STS approach related to other research topics (represented here by keywords). In this way, we construct a network, from the centrality measures calculated in this work, in which STS is positioned in the center of the image, as if it were a nucleus, and the other subjects are placed around it, as if they were orbiting it (Figure 2).

To better visualize the position of each theme in the network, we divide our sample into the following partitions: the first one contains the STS keyword and it is the most centralized in the network; the second, concentrated closer to STS, is the partition with the other 20 keywords of Table 1; and the third partition is formed by the remaining 153 keywords.

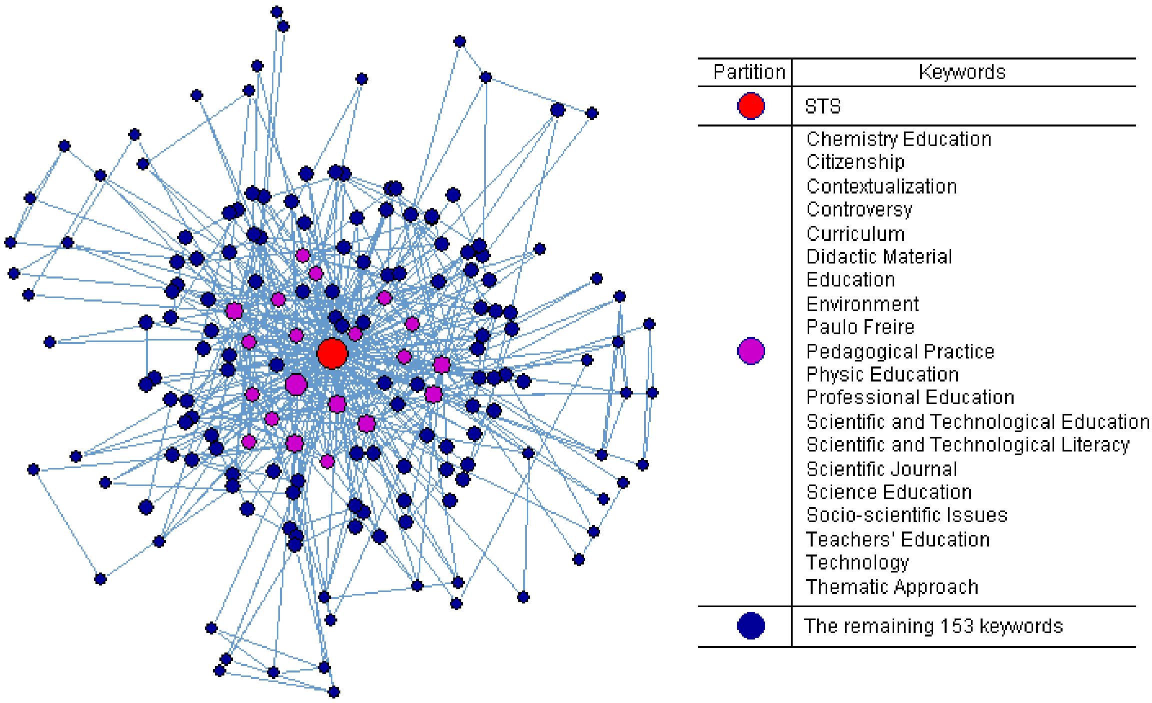

Figure 2. Network of keywords linked to STS

In the image shown in Figure 2, we can see the vertices (keywords) represented by the circles, and the connections between them (edges) by the lines that connect them. Two types of filters, based on the centrality measures previously presented, were represented: size and color. The larger the circle representing the respective keyword, the greater its position in the ranking of centralities.

Thus, the central circle, representative of STS, is the largest of all, and those that orbit it follow the different gradations. Colors refer to our field of cut. In the impossibility of dealing with all themes, we chose the first 20, based on the centrality criteria adopted. For being the center of the network, STS presents a red (or lighter) color, the first 20 themes are shown in fuchsia (or intermediate color) and the 153 remaining keywords are presented in dark blue (or darker).

Therefore, Figure 2 shows the field of STS studies is extremely heterogeneous. In 137 articles analyzed, we found a variety of 174 vertices, that is, 174 different keywords.

It is necessary to emphasize that, in addition to having more than one keyword; each article had at least one keyword different from the others, which explains the variety of works. In our opinion, divergences do not result in a lack of STS identity, but may represent an interdisciplinary aspect associated with the theme.

We also find that most of the keywords that occupied the first positions are closely related to scientific education. Thus, the articles are coherent, linking the field of education to the STS field. However, we could not fail to observe the absence of some foundational themes of STS (for example, sociology of science and technology, and science and technology policies) in the education articles analyzed.

In the transposition of ideas from one field to another, as in the ideas of STS for education, we believe that it is extremely important to visit the founding fields, which avoid the distortion of ideas or the compartmentalization of a multi-modal area, as our own results demonstrate.

Finally, it is necessary to emphasize that the analysis of networks allows us to provide an overview on how an area behaves, be it STS or any other. The chosen methodology, although is not as popular as others in education area, presents a view of the data capable of bringing amplitude and the treatment of a large amount of data.

As well as methodologies of content analysis and its derivatives, it presents categorizations taken from the material of analysis itself, not qualitatively but quantitatively. This allows us to deal with as many articles as literature offers us. This differentiated approach has resulted not only in new information, but also in new possibilities for study design, management, understanding and perspective of biases and gaps in the STS area.

Relational aspects of keywords orbiting STS

In order to analyze how the themes that orbit STS are related to this area, we searched, in the texts that composed our scope of research, for qualitative elements that could provide the connections found by us. It is worth noting that some of the keywords are discussed conceptually in the articles, while others are highlighted for being empirical elements of the mentioned researches. For this reason, in this text, we will offer different views to each term, based on the emphasis that the articles in analysis present.

The term "scientific and technological education" is used generically in the literature to indicate any attitude that transposes scientific and technological knowledge to the educational objective, apart from the objective of the scientific and technological enterprises themselves, and may be related to the contexts of empowerment (VALENTE, 2002) or to the solutions for low academic performance and the reduction of students' interest in scientific and technological areas (DEMO, 2004).

In addition to these restricted meanings, there is still the possibility of interpreting the term in its broadest and most interdisciplinary sense: the promotion of scientific culture (CACHAPUZ; PRAIA; JORGE, 2004). From this point of view, it is no longer possible to maintain education without asking "what for", to the same extent of "how" and "what". The discussions on STS "[...] indicate a need for exploiting knowledge in a broader way" (ANGOTTI; AUTH, 2001, p.23). This view converges with the objectives of contemporary scientific education and, consequently, makes this approach one of the possible paths in the pursuit of this objective, since:

> Science as culture values the formative and cultural dimension of scientific education. The recognition of the cultural and ethical value of science, in its interactions with technology and society, is not recent at all. (SANTOS, 2009, p. 534)

Concerning scientific and technological literacy, despite the difficulty of delimiting the concept (LAUGKSCH, 2000), we found a similar scenario, since this expression is a theoretical conception. In an attempt to elaborate the possible meanings of scientific and technological literacy, Vázquez et al. (2003, p. 82–83, our translation), use various authors to treat them in three different ways:

- A slogan that summarizes, as a keyword, the purposes of science education reform in a broad international movement of specialists in scientific education.
- A Metaphor that serves to express in general way the aims and objectives of scientific education.
- A cultural myth that can be reformulated as a utopia that represents an ideal to be pursued, although originally expressed from a critical perspective.

In addition, scientific and technological literacy can extrapolate the space of the school, when emphasizing its universal character aiming at the *slogan science for all citizens*. In this sense, Chassot (2003) argues that, more than a proposal, scientific literacy is an opportunity for social inclusion, although the struggles of its realization are under debate.

Crowning the undoubted relationship between scientific and technological literacy and STS thinking in general, Dagnino (2014), who also provides a glimpse of a strategy for social inclusion in scientific and technological literacy and in the STS fields, expands the horizons of STS education. In this way, the close relationship between scientific and technological literacy and STS education, evidenced by our analysis of the publications of the area, is not only justified, but also presented as a pressing concern in contemporary science education.

Recognizing that education is one of the pillars of contemporary society (CARDINALI et al., 2012), the articles dealing with the STS approach found in this field usually present an attempt to re-signify science education as exposed by formal education, as highlighted by Siqueira-Batista et al. (2010):

> The "nature" of the natural sciences, their relations with technology –

> rarely thought in terms of technoscience – and their role in education for life in society are recurrent themes in the thinking agenda in the West, over the last few centuries. (SIQUEIRA-BATISTA et al. (2010) p. 480)

To this end, a distinction must be made between science and technology education and science education (or specific disciplines), even though it is not possible to draw clearly defined limits. Education is a very specific process, peculiar to the school environment, in which the learning of a specific content is the focus and there is a well-planned systematics, with the purpose of making the students reach a minimum knowledge established by didactic issues.

Education has a broader meaning and embraces the meta-knowledge of the local and global environment. Therefore, it can be present in several contexts, whether formal or non-formal (PORTO; ZIMMERMANN; HARTMANN, 2010). Thus, when it comes to scientific and technological education, especially under the STS approach, the educational context refers to issues not only internal to science and technology, since this knowledge is not disconnected from reality (TEIXEIRA, 2003).

Some solutions are pointed out in research in science education area in order to place scientific content in a space-time. For example:

- Gurgel and Mariano (2008) propose the introduction of history and sociology of science in science education so that "apprentices recognize Science and Technology as human products, marked by successes and failures, as a result of social and cultural complex conditions, conflicts, differences of attitudes, values and ways of thinking of historical groups" (p. 69).
- Porto, Zimmermann and Hartmann (2010) stimulate the interaction between museum and school, believing "that formal and non-formal education reinforce each other and that museological activities motivate learning" (p. 55), in the specific case of this research, learning physics.
- Santos, Amaral and Maciel (2010, 2012a, 2012b) use chemistry classes in professional education to work on topics involving elements of experimental chemistry, such as soap, detergent, cachaça and beer. According to the authors, chemistry education, under the STS approach, enhances the increase of dialogic interactions in the classroom.
- Also in professional education, Araújo and Formenton (2012) have appropriated the STS approach to address alternative sources of automotive energy in physics education, aiming to provide a broader education, encouraging human values such as solidarity and collective good.

As can be seen, the STS approach in science education seeks to reconcile disciplinary contents with broader social facts. In this sense, contextualization appears as an ideological tool used in several educational environments. By contextualization in STS, we understand the action that "privileges the study of social contexts with political, economic and environmental aspects, based on knowledge of science and technology" (SILVA; MARCONDES, 2010, p.105).

Macedo and Silva (2010) point out the need to recognize in which contextualization perspective a work is based on, since there are at least five of them identified by the authors: contextualization as a statement of ordinary and everyday facts; the contextualization for exemplification and applicability of concepts; the historical socio-cultural contextualization; the contextualization submitted to the productive system and the labor market; and the articulating contextualization of social themes and scientific and technological concepts.

The contextualization that articulates social themes and scientific and technological concepts is the most privileged by the STS approach. One of the concerns of researchers in the area is on how it occurs in didactic materials, when it happens (MACEDO; SILVA, 2010; SILVA; MARCONDES, 2010).

It is recognized that few didactic materials contextualized in the way expected by the STS approach are easily found to be used by professors from the scientific and technological areas (AMARAL; XAVIER; MACIEL, 2009; TRÓPIA; VIANA; GUIMARÃES, 2013). Thus, a possible exit would be the promotion of research aimed at the construction of customized materials that allow the creation of scenarios in which knowledge is a key to the solution of problems (SAMAGAIA; PEDUZZI, 2004).

The choice of didactic material to be used in teaching is a curricular issue, but "the notion of curriculum development essentially refers to its construction process, i.e., its conception, implementation and evaluation" (FERREIRA; MORAIS; NEVES, 2010). Thus, for Ferreira, Morais and Neves (2010), the construction and maintenance of a curriculum is a process that must be collaborative, involving several entities with different perspectives of the teaching-learning process, as this is an imminently political process situated in a space-time.

The orientation of the curriculum through the STS approach has among its objectives to overcome a hegemonic curriculum, called traditional, that is focused exclusively on disciplinary knowledge and skills. Social issues should be present not only in the official curriculum of science education, but also in schools, in order to provide an important interaction for democracy, involving science, technology and society (AMORIM, 2001; CASSAB, 2008).

For this, one of the concepts that should be approached by the curricula oriented by the STS is the technology and its diverse conceptions – although this diversity is not worked in science and technology education, at school, in its amplitudes (SILVA et al., 2015). This fact is attested by Böck's recent research (2014), showing that in the universe of articles we used for this research, only 1.72% of them were written by specific authors in the area of technology. Veraszto et al. (2013) present several conceptions about technology: intellectualist (progressive and cumulative processes); utilitarian (technology as synonymous with technique); technology as synonymous with science; instrumentalist (technology as synonymous with technological artifacts); neutrality (technology is neither good nor bad); determinism (self-evolutionary technology); universality (technology independent of sociocultural context); technological pessimism; technological optimism; and socio-system. Agreeing that "technology is determined by the interaction of different groups through social, political, economic, environmental and cultural relations, among others" (VERASZTO et al., 2013, p.765) the STS authors consider that the idea of a socio-system is propitious to be worked in technological education (SILVEIRA; BAZZO, 2009).

Another highlight in STS-driven curricula is the environment. Environmental issues have been, and are, in a prominent position in the discussions around the social construction of science and technology, and especially in the speeches that reveal the negative impacts of the use of science and technology. This may be represented by the appreciation of Rachel Carson's publication, "Silent Spring" (1962), which is listed by the STS movement as a precursor work, once it promotes the debate on the use of non-organic substances, such as DDT (dichloro-diphenyl trichloroethane) and BHC (benzene hexachloride) in insecticidal and herbicidal practices.

According to Carson, at the time, these materials were used indiscriminately, and consequently, spring arrived "unannounced by the return of the birds; and the dawns appear strangely silent, in the regions where once they were filled with the beauty of birds' song" (CARSON, apud ARAÚJO; SILVA, 2012, p. 104).

To discuss the environmental theme in a STS approach is not to intertwine the environment with technicist decisions, whose objective is to leave science above conflicts and environmental disputes and to naturalize environmental degradation as a price to be paid for technological progress (SILVA; CARVALHO, 2012). The STS approach brings the discussion to a more social level, seeking to make the society-nature relationship critical, positioning man as part of nature and co-responsible for environmental risks.

From the moment it is reflected on the context of the production of scientific and technological knowledge, other controversial issues emerge, besides the environmental ones. The debate about the nature of science and technology touches on points that do not present consensus. Construction of criticality is part of STS education, so that the subject is able to deal with the diverse opinions present in the context in which science and technology are not the only elements among several decision-making assumptions.

For Reis (2005), bringing controversies to education generates potentialities:

> a) In the construction of a scientific culture indispensable for a participatory citizenship.
>
> b) In the construction of knowledge relevant to life in society, communicating the idea that school is not something apart, dissociated from real life.
>
> c) In the motivation of the students and in the stimulation of their curiosity.

> d) In the intellectual development of students, in particular, through the promotion of critical thinking skills.
>
> e) In the moral development of the students through the clarification of values.
>
> f) In the construction of a concept of science as an enterprise: (1) human, influenced by values; and (2) collective, whose progress depends decisively on the discussion of ideas and opinions.
>
> g) In the change of a concept of science as a well-defined discipline, with secure answers in which uncertainty, doubt and debate are not admissible. (p. 155)

The use of controversy in science education refers directly to STS education through socio-scientific issues. In the STS approach, a theme is not only an introduction to a scientific knowledge, it composes a whole scenario that reveals the complex interaction among science, technology and society. According to Santos, Amaral and Maciel (2010), the approach through socio-scientific issues enhances the interaction process in the classroom through lived situations, exposing attitudes, values and conceptions about science and technology.

In the Brazilian studies, there is an attempt of convergence between the STS approach and the proposal of the generating themes of Paulo Freire. Auler (2003) has called this confluence the "thematic approach". For this author, although there is no consensus on the choice of themes between the Freirean assumptions and the works with the STS approach, this approximation provides a critical understanding of Science-Technology-Society interactions, with an attempt to overcome the technocratic model of decisions, from the salvationist, redemptive perspective attributed to Science-Technology, and from technological determinism; it contributes to overcome the propaedeutic education; and it is an alternative to merely disciplinary education.

Another theme of proximity in the orbital around STS are the scientific journals. Science is present in the STS triad and the dissemination of results through journals is one of the most tangible products of the production of scientific knowledge. For this reason, scientific journals are within the scope of Brazilian research production under the STS approach, either as a pedagogical-epistemological element, as in Cardinali et al. (2012), or as an object of research, as in Chrispino et al. (2013a).

Final considerations

The impacts and developments of science and technology have been at a pace that is still incompatible with our capacity as an organized society to analyze, evaluate and critically decide on its performance and its direction. The effort of Brazilian researchers to overcome this challenge, by defending the STS approach in education, can be better understood by presenting the most central themes of their approaches, which also sheds light on a multidisciplinary area in expansion and with no boundaries defined. The contributions to the development of the area are fundamental to the current scenario, in which researches point out that the conceptions about the interaction among science, technology and society are naively interpreted by the teachers, since their initial education (GURGEL; MARIANO, 2008). In this context, we realize that frequently the conceptions at the end of the graduation, and in the daily practice of the teachers already in practice, are often as naive as the conceptions of undergraduates at the beginning of their course (BENNÁSSAR et al., 2011) – conceptions generally distorted about technology are one of the cases in which this occurs more clearly (CHRISPINO et al., 2011).

Some studies point out that a possible pathway for conceptions to become more appropriate is to discuss and implement pedagogical practices, under the STS approach, with teachers in initial education and with teachers in practice (CASSIANI; VON LINSINGEN, 2009; TENREIRO-VIEIRA; VIEIRA, 2005). Visualizing the STS approach as an academic field orbited by various research themes helps to understand how we are building this path. In fact, this overview makes it possible to perceive strengths and weaknesses in the production set, in the same way that it identifies tendencies and intentionalities of STS Education.

The analysis of this arrangement points out an alignment of the focus of the researchers with relevant institutions of the area, treating science and technology education and science education as more relevant themes. This is because national and international institutions such as Esocite-BR (Brazilian Association of Social Studies on Science and Technology), 4S (Society for Social Studies of Science) and EASST (European Association for Studies of Science and Technology) strongly recommend the development and promotion of STS education at various levels of education. However, it also presents technology as a less relevant theme, precisely the one in which students and teachers present more naive and mistaken conceptions, as presented above.

The qualitative analysis of these connections, carried out in the section "Relational aspects of keywords orbiting STS", generated a revision of the STS approach in education, based on the Brazilian academic production on education area, which contributes to the consolidation of the area, besides future research on the STS line.

In this review, the STS approach has emerged as a research theme that has affinities with others, receiving contributions from several areas, which reinforces its open and multidisciplinary character. An inference that we make – upon perceiving the richness of the orbital analyzed – is that STS represents more than a set of techniques or a theme owned by a group of researchers. STS represents a cultural medium that channels various sources in order to contribute to the development of a critical, historical and contextualized view of the organization, production and application of science and technology as a social process.

A next stage may contemplate a study of the relations of these keywords with authors of the articles analyzed, as well as with the institutions to which they are affiliated, allowing us to know the view and the particular approach of each author and institution in the great area of knowledge that is STS Education.

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