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Science Education Mediated by the Art-Science Axis

Educação Científica Mediada pelo Eixo Arte-Ciência

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ABSTRACT

This study sought to analyze the academic production linked to the Art-Science scenario in the annals of the National Meeting of Research in Science Education (ENPEC). To do so, were analyzed the productions in the annals of all available editions from the 1st to the 12th. The articles were searched through the term "art", therefore only those that contemplate the Art-Science axis have been selected for analysis. The articles of interest selected for the study were carefully examined to capture information, especially the scientific and artistic aspects involved, and they were subsequently submitted to Statistical Implicative Analysis to establish an inference of possible relations of implication between variables. From the analyses, it was possible to verify a significant diversity of artistic expressions being linked to teaching and learning of scientific themes, mainly in the fields of Biological Sciences, Chemistry and Physics. Based on the results, it is possible to affirm that the intersections between Art and Science significantly contribute to teachers and students at different educational levels. Furthermore, it can be inferred that Art-Science axis constitutes a fertile field for developing research in Science Education.

Keywords: Art-Science; Science Education; Interdisciplinarity.

RESUMO

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Este estudo buscou analisar a produção acadêmica vinculada ao cenário Arte-Ciência nos anais do Encontro Nacional de Pesquisa em Educação em Ciências (ENPEC). Para tanto, foram analisadas as produções nos anais de todas as edições disponíveis, da 1ª à 12ª. Os artigos foram buscados por meio do termo "art", assim foram selecionados para análise apenas aqueles que contemplam o eixo Arte-Ciência. Os artigos de interesse selecionados para o estudo foram criteriosamente examinados para captar informações, especialmente os aspectos científicos e artísticos envolvidos, e posteriormente submetidos à Análise Estatística Implicativa para estabelecer uma inferência de possíveis relações de implicação entre as variáveis. A partir das análises, foi possível verificar uma diversidade significativa de expressões artísticas vinculadas ao ensino e aprendizagem de temas científicos, principalmente nas áreas de Ciências Biológicas, Química e Física. Com base nos resultados, é possível afirmar que as intersecções entre Arte e Ciência contribuem significativamente para professores e alunos de diferentes níveis educacionais. Além disso, pode-se inferir que o eixo Arte-Ciência se constitui em um campo fértil para o desenvolvimento de pesquisas em Educação em Ciências.

Palavras-chave: Arte-Ciência; Educação em Ciências; Interdisciplinaridade.

INTRODUCTION

Since ancient times, humanity has had different ways of interacting with the world, and of representing such synergy in an iconic way. It suggests that it was consolidated through human need to understand and explain the universe around them. Based on the ability to observe and reproduce characteristics of the environment, humans started to use different ways to explain everyday phenomena, especially those of a biological nature.

Cave paintings can be highlighted among the ways in which prehistoric humans contemplated and expressed scenes of the environment in which they lived (Santos; Garcia, 2019), constituting an archaic type of art making. Furthermore, other paths were possible to be followed in addition to representing the environment, also studying it and exposing it to the world through art.

Same problem as comment 1, it is possible to verify that different ways of observing, understanding, and explaining the world were being established practically simultaneously. However, such proposals to explain/demonstrate phenomena in the world were historically seen as divergent points.

Art and Science can be allied, above all, regarding the methodological proposals of Biology Teaching. Thus, these fields can compose the Art-Science axis. This axis corresponds to interdisciplinary teaching proposals based on intersections between the areas of Art and Science, in which activities are developed that unite art and science with educational purposes.

In this axis, it is possible to find varied proposals that aim to teach biological concepts, for example, through scientific illustrations that explore the art of illustrating to promote scientific learning (Moura; Silva; Santos, 2016), the teaching of cell biology associated with art mediated by technology (Elias *et al.*, 2019), as well as contemplating, recognizing and promoting art as a means that enables studies in human anatomy throughout history (Janeiro; Pechula, 2016). The Art-science axis confers great importance in the teaching-learning process, contributing to scientific education (Deccache Maia; Santos; Nunes, 2017).

The contributions of this axis can be seen from the publication of scientific content in scientific events. These events make it possible to update different topics for different researchers (Lacerda *et al.*, 2008), in addition to providing opportunities for the emergence of new discussions in the scientific sphere.

From this perspective, we seek clarification on the following question: How is the Art-Science axis approached in works published in the annals of the National Meeting of Research in Science Education? This clarification is needed because this axis has ample importance for the training of scientifically constructed subjects at the same time as artistically sensitized. In addition, the aforementioned event has broad relevance to the field of Science Education in the Brazilian territory as well as internationally, as it attracts audiences of different nationalities.

In light of the previously mentioned topic, this study aims to analyze the academic production linked to the Art-Science scenario in the proceedings of the National Meeting of Research in Science Education and, in doing so, to raise reflections on the works found through Statistical Implicative Analysis

(SIA), which seek to analyze implication and similarity between different variables.

Confluences between Art and Science: perspectives for Biology Teaching

Art and science are components of human creation which for a long time were seen as products that have little or no association to each other, especially because art emerges from creative processes based on feelings, emotions, and subjectivity, while science is antagonistically based on results from concrete, objective and mainly rational processes. Thus, since they deal apparently with quite different themes which throughout history were situated in divergent positions, they are observed by many scholars only in terms of their respective differences.

However, when we look at the History of Science, it is possible to verify that this strong dissociation between both areas did not occur in that exact way. This is mainly because artists and scientists were focused on observations, explanations, and representations of the world from their own perspectives. Thus, it is certain that eventually, both perspectives were able to follow common paths, mainly because they reported similar eventualities (Silva; Guimarães, 2004). In fact, it is possible to verify convergences between scientific work combined with artistic expression since the 15th century through the work of the Italian Leonardo di Ser Piero da Vinci (Cachapuz, 2014).

When observing Da Vinci's contributions, the (complementary) relations between Art and Science are significantly noticeable from a perspective in which there is no possibility of systematically dissociating both expressions because they are the result of human creative processes. However they have been seen as divergent, they actually are consistent in representations of the empirical world. Thus, taking Da Vinci as an example, it is possible to mention his work entitled "The Vitruvian Man" (1490), which encompasses artistic-scientific methods in its composition. It uses art from drawing and painting techniques, while obtaining and expressing its vision of science through the use

of medical techniques and knowledge, as well as dissection (Janeiro; Pechula, 2016).

The aforementioned authors reiterate that these associations occurred in other works, including those of other artists in the 15th century and in subsequent periods until contemporary times. They then elucidate that although they were treated as distinct issues, they acted together in the development of human history with regard to science and culture.

In this context, it is important to raise awareness of the contributions that the Art-Science relationship can make in the field of Science Teaching, since proposals that aim to articulate these knowledge areas enable connections between man, scientific knowledge and culture, as well as spiritual, biological, and historical aspects (Silva; Guimarães, 2004). As a result, promoting students' thoughtfulness, critical thinking and creativity (Elias *et al.*, 2019) in interdisciplinary, playful activities that involve knowledge construction in a pleasant way (Duarte *et al.*, 2018).

Thus, combining Art with Science (and vice versa) in the Science Teaching line consists of establishing strategies that enable making educational spaces attractive, especially the school environment (Elias *et al.*, 2019), and this may rescue or awake the interest of students in learning about the most varied concepts and processes (Nascimento Júnior; Souza, 2009). Therefore, subjects need to relate in various ways with the object under study aiming effective learning, which by observing, interacting and experiencing moments of active and reflective participation are ways then to possibly achieve these goals from actions involving Art-Science, especially those that value and encourage the use or evocation of students' skills (Duarte *et al.*, 2018; Elias *et al.*, 2019).

Moreover, it is possible to highlight that individuals involved in the teaching-learning processes feel motivated and like to participate in proposals that exchange between the fields of emotion and reason, combining subjectivity and objectivity in the perspective of complementarity and interdisciplinarity. In this perspective students highlight the potential of this type of approach, mentioning its potential to promote knowledge and broaden

the worldview (Nascimento Júnior; Souza, 2009; Feitosa, 2021), as well as highlighting the attractiveness of these areas as a motivating factor for learning (Elias *et al.*, 2019).

Regarding professors Duarte et al. (2018) emphasize that self-esteem is raised by enrolling activities involving the fields of Art and Science, this contributes to achieving educational and teaching goals. It is noteworthy that the "insertion of Art in Science Teaching can occur in different ways at all education levels, involving different artistic works and in different educational contexts, including formal and non-formal" (Nascimento Júnior; Souza, 2009, p. 5, 2009).

Thus, performing educational activities requires a sensitive look from teachers about the possibilities, and teachers must have contact with interdisciplinary teaching perspectives in the course of initial training (Duarte *et al.*, 2018), especially considering the interactions between the scientific and artistic fields enabling the use of different methodologies, which intend to support improvements in teaching practice (Moura; Silva; Santos, 2016). It may be unclear who or what "this" refers to provides opportunities for teachers to modify the bureaucratic aspects of their routines in educational institutions (Cachapuz, 2014).

In this sense, if one observes the field of Biological Sciences, it is possible to glimpse different possibilities for teachers to use Art in Science and Science in Art, not only aiming that students understand and grasp biological concepts, but also have them awaken their creativity and critical thinking; in addition to promoting culture in attractive and pleasurable activities. Thus, it is possible that Biology is seen in a collaborative way with the various types of artistic expressions, for example, in proposals for teaching biology mediated by sculpture (Bussi; Miquelin; Leal, 2019), painting (Miquelin; Amaral, 2019), drawing (Araujo *et al.*, 2013), music (Rehem *et al.*, 2013), cinema (Almeida *et al.*, 2019), theater (Campanini; Rocha, 2017) and photography (Brito *et al.*, 2017).

Therefore, practices that aim to contemplate this interdisciplinary perspective between Biology and Art are pertinent, as in addition to

contributing to critical thinking, creativity, and cultural immersion, they also enable a break with Cartesian teaching proposals strongly based on the fragmentation and memorization of school contents (Silva; Guimarães, 2004). Consequently, it consists of the perspective of Biology undergraduates having an approach that can alleviate difficulties linked to abstraction, contextualization, and dissemination of science to the non-specialized community (Nascimento Júnior; Souza, 2009).

Furthermore, it is also pertinent to use Art and Science in the educational sphere, taking advantage of the perspective that teaching and learning in Biology occur in different ways, being then enhanced by the synergy between these knowledge fields (Duarte *et al.*, 2018; Elias *et al.*, 2019). Thus, enabling innovations and perspectives for Science Teaching in the most diverse contexts and training environments, whether formal or non-formal (Rocque *et al.*, 2007).

Scientific events in Biological Science Teaching

With the expansion and development of different knowledge areas and their specializations, thematic societies emerged which aimed at organizing events, seeking to share and present what had been produced in their particular area, since in the past, communication between researchers took place through letters (LacerdA *et al.*, 2008). In this sense, Carmo and Prado (2005, p. 131) state that: “Science as a social activity needs to be disseminated, debated, and reflected upon.”. Thus, scientific information must be updated, making use of the most diverse forms of communication (Lacerda *et al.*, 2008).

According to Meadows (1999), scientific communication can be delivered in two ways: formal and informal. The author emphasizes that the formal way only depends on vision, pointing to books and journals as examples, while the informal takes place through speech, without an official record, such as some congresses and conferences. From this perspective, scientific events are classified as an informal way of scientific communication, which makes it possible to update information for each participant in their field of study (Lacerda *et al.*, 2008).

Along these same lines, Schmidt and Ohira (2002, p. 73) state that "Scientific events are considered highly efficient means of oral communication of knowledge, in view of the increasing pace of science development". Thus, oral communication's role in disseminating knowledge is evident.

Additional hours and extracurricular activities are required during academic training, such as scientific initiation activities, extension, and participation in scientific events; according to Lacerda et al. (2008), activities such as participation in scientific events in parallel to the subjects being taken are identified as important and essential for the student's education.

Thus, scientific events have been shown to be relevant for scientific communication and dissemination, being characteristic for bringing together students and professionals from the most diverse areas, enabling an exchange of knowledge and common interests (MarchiorI *et al.*, 2006; Lacerda *et al.*, 2008). These events can provide various functions such as meetings to improve the work presented, understanding the state of the art in certain areas, as well as the informal exchange of knowledge that takes place among the participants (Campello, 2000; Marchiori *et al.*, 2006).

Scientific events can also be divided into congresses, symposia, seminars, meetings, and conferences (among others), and specific times are defined for debate to take place among participants (Carmo; Prado, 2005; Severino, 2013). In addition, within them, there are two types of work presentations: oral (speeches/lectures) and posters (Lacerda *et al.*, 2008). Such exhibitions only occur after approval by defined commissions (Carmo; Prado, 2005).

Among the main characteristics of scientific events, we can highlight the publications of works that are presented in events such as annals, and which, according to Gomes, Mendonça, and Souza (2000), represent a type of literature that is not available in commercial media. In this sense, it is called Gray Literature, as it is able to flow and spread quickly, in addition to representing 90% of the information that many researchers use (Poblacion; Noronha; Currás, 1996).

Moreover, these collaborate with the student's training and allow them to have full access to what was presented by each participant (LACERDA et al.,

2008). For Campello (2000), event annals represent provisional documents, serving as an initial source that may later become articles to be published in scientific journals, increasingly contributing to the scientific dissemination process.

Several national and regional events related to teaching Biological Sciences stand out in Brazil, such as the National Meeting of Research in Science Education (ENPEC), the National Meeting on Biology Teaching (ENEBIO), and the Regional Meeting on Biology Teaching (EREBIO). Each event has different themes throughout each edition and allows discussion and debate on a wide range of subjects.

Considering the diversity of events in the fields of Science and Biology Teaching, there is also a great diversity of works that are published in the annals. Thus, given the variety of proposals that each work can offer, it is necessary to verify the different perspectives and approaches that such researches point to Biological Science Teaching, especially with regard to the Art-Science axis.

METHODOLOGICAL COURSE

This study presents a quantitative-qualitative approach that establishes complementary relationships between quantitative and qualitative research lines (Souza; Kerbauy, 2017). It is a literature review seeking to investigate themes from available textual productions that are the result of previous research (Severino, 2013). In this study, we sought to understanding academic productions linked to the Art-Science field in articles published in the Annals of the National Meeting of Research in Science Education (*ENPEC*) in Brazil.

This event was selected because of its relevance to the field of Science education in Brazil, and can it be considered a prolific field for scientific production, promotion, and dissemination. In this sense, surveys were carried out in publications surveying the Art-Science interface to select relevant productions for the study. For the survey and selection of works of interest, which in this case represent the research subjects, searches were carried out

in the annals available between editions I (1997) and XII (2019). Among the editions mentioned, only the number VII (2009) was not investigated since its website is corrupted, making the search and consequent analysis of the productions of that edition in question unfeasible.

The search for works in the annals was carried out manually in the I ENPEC, since the works are arranged in a software-type file that does not have a search tool. The other issues were investigated using the browser's search tool (Ctrl+F). The term "Art" was used in the searches to contemplate a wider range of possible results with regard to works involving art or artistic expressions in proposals aimed at teaching Science and Science Education. Next, titles, abstracts, and, when necessary, other topics of the texts were read to select and include the works searched.

After screening the works of interest, they were submitted to Statistical Implicative Analysis (SIA), in which we intended to verify implicative relationships between the stipulated variables, making it possible to establish relationships between the results that transcend the exclusive use of descriptive statistics (RÉGNIER; ANDRADE, 2020). ASI makes it possible to identify implication relationships between different variables, which can be quantitative (continuous or discrete) or qualitative (nominal, ordinal or textual). These implications allow us to verify how one variable can be related to another through statistics and probability. Therefore, it was necessary to use a software called CHIC (Hierarchical Implicative and Cohesive Classification).

The software works by extracting a set of data, crossing the information and variables, to provide association rules between them, and thus providing a quality index of these associations, and representing this structure through implicative and similarity graphs. These graphs visually represent how each variable may be implying another, an aspect that would be difficult to recognize just through a basic analysis without the use of software (RÉGNIER; ANDRADE, 2020). Thus, categories and variables were used (Chart 1) to perform this analysis, which was coded for processing in the CHIC software program using

only the resources directed to the SIA through implicative graphs. Such data were

Table 1. Categories used in data processing in the CHIC software.

Category	Variable	Code
Event Edition	Edition 1	V01Ed1
	Edition 2	V01Ed2
	Edition 3	V01Ed3
	Edition 4	V01Ed4
	Edition 5	V01Ed5
	Edition 6	V01Ed6
	Edition 8	V01Ed8
	Edition 9	V01Ed9
	Edition 10	V01Ed10
	Edition 11	V01Ed11
	Edition 12	V01Ed12
Event Region	South	V02ReES
	Southeast	V02ReESE
	Northeast	V02ReENE
Research Region	North	V03RePN
	Northeast	V03RePNE
	Midwest	V03RePCO
	Southeast	V03RePSE
	South	V03RePS
Knowledge area	Biological Sciences	V04ArCiBio
	Chemistry	V04ArCQui
	Physics	V04ArCFi
	Math	V04ArCMat
	Not applicable	V04ArCNA
Teaching level/modality	Kindergarten	V05NiEInf
	Youth and Adult Education	V05NiEJA
	Elementary School	V05NiEFu

	High school	V05NiEMe
	University education	V05NiESu
	Not applicable	V05NiENA
Artistic expression	Music	V06ExArMu
	Movie theater	V06ExArCine
	Sculpture	V06ExArEsc
	Painting	V06ExArPin
	Cyber art	V06ExArCib
	Design	V06ExArDes
	Literature	V06ExArLit
	Dance	V06ExArDan
	Photography	V06ExArFot
	Theater	V06ExArTea
	Comic book	V06ExArHQ
	Not applicable	V06ExArNA

Source: The authors.

In this sense, the event's Edition, Event Region, Research Region, Knowledge Area, Teaching Level/Mode, and Artistic Expression were defined as analysis categories in the event. Each category is subdivided into its respective variables which represent its specifications. Then, codes were established that specify the junction between categories and variables to carry out data processing on the CHIC platform.

RESULTS AND DISCUSSION

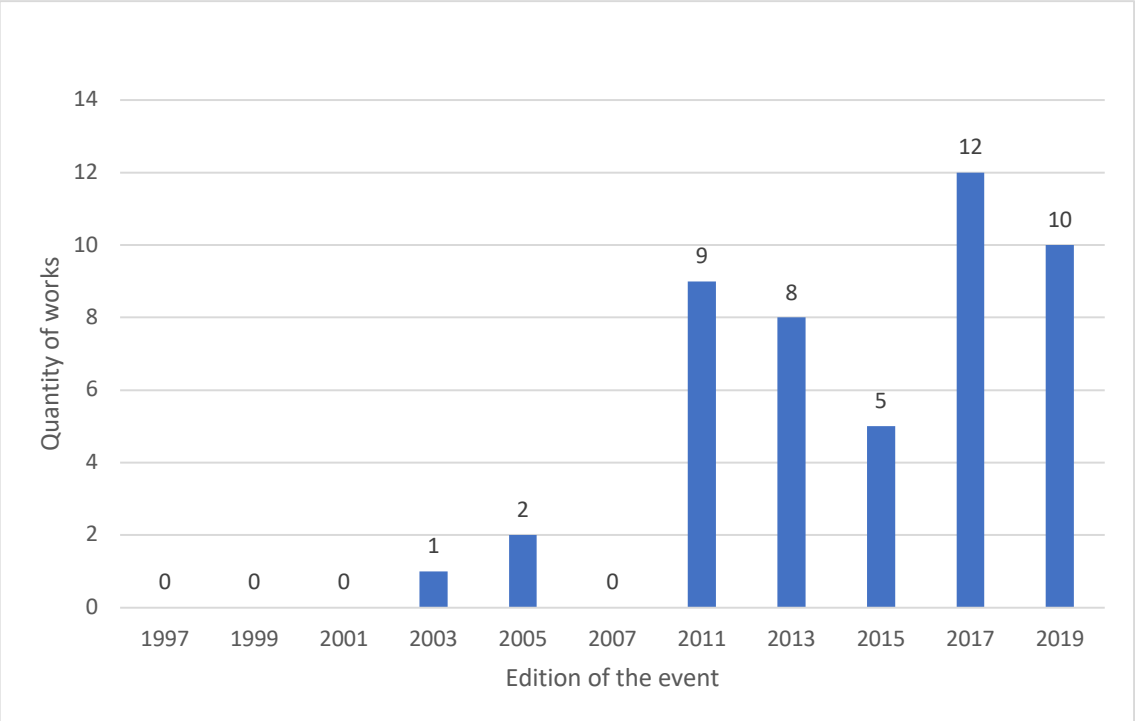
A total of 47 articles were collected in the annals from Editions I to XII of *ENPEC*, from the surveys and selection of works relevant to this study which relate to the Art-Science axis. Such works range from experience reports, situating artistic elements for contributions in the act of teaching and learning science and biology, to theoretical discussions on the thematic axis, exposing rich contributions from teachers and researchers to science education at all teaching levels in Brazil.

Next, we will deal with data analysis from the perspective of descriptive statistics, generally presenting the data of each category and its specificities. Later we will use of Statistical Implicative Analysis (SIA) to seek to direct reflections on the implications of the variables chosen for analysis.

Category 1: Event editions

From the analysis of the annals of the editions available at *ENPEC that* took place between 1997 and 2019, it was possible to establish that art linked to science had a timid insertion. The first record dated only in 2003 in the fourth edition of the event, with only one production. However, the numbers relatively increased in some later editions, as they can be seen in the graph in Figure 1.

Figure 1. Number of works related to the Art-Science axis per edition of the event.



Source: The authors.

From what was shown in the graph above, it is possible to observe that even with the timid inclusion of the Art-Science perspective in proposals published in the annals, there was a relative tendency towards an increase in

the number of works in this perspective as the editions passed. Even so, the number does not follow a rising per se, since there exist editions of the event in which there were no articles published in this field, as in the editions of 1997, 1999, 2001, and 2007.

It is noteworthy that only the seventh Edition (2009) is not shown in the figure due to technical failures in the Brazilian Association in Science Education (*ABRAPEC*) platform. The link available to access the works directs to the website of another institution, making access to the annals unfeasible. Other researchers have already reported this problem, but it persists, as there is still no solution.

The lower frequency of works related to the Art-Science axis at the event can be justified, since this axis has recently been consolidated in Brazil. Although there are a few records from the 20th century, it was only from the 21st century onwards, specifically in the 2010s, that the quantity of works in this axis showed a significant increase (Feitosa, 2021).

Thus, this field of studies can be characterized by a rising status on the national scene, which reinforces the need for research that draws connection between these areas, promotes new knowledge construction, and expands the worldview of students who experience these teaching proposals (Nascimento Júnior; Souza, 2009).

It is worth emphasizing here that we will not look into the specific methodologies that the works used in the relationship between the axis that is the object of study, as the intention is to verify only the implicative relationships that can be raised between the studied variables.

Category 2: Event regions

The Southeast region is highlighted among the regions where the event's editions took place. It hosted eight of the 12 first editions, followed by the

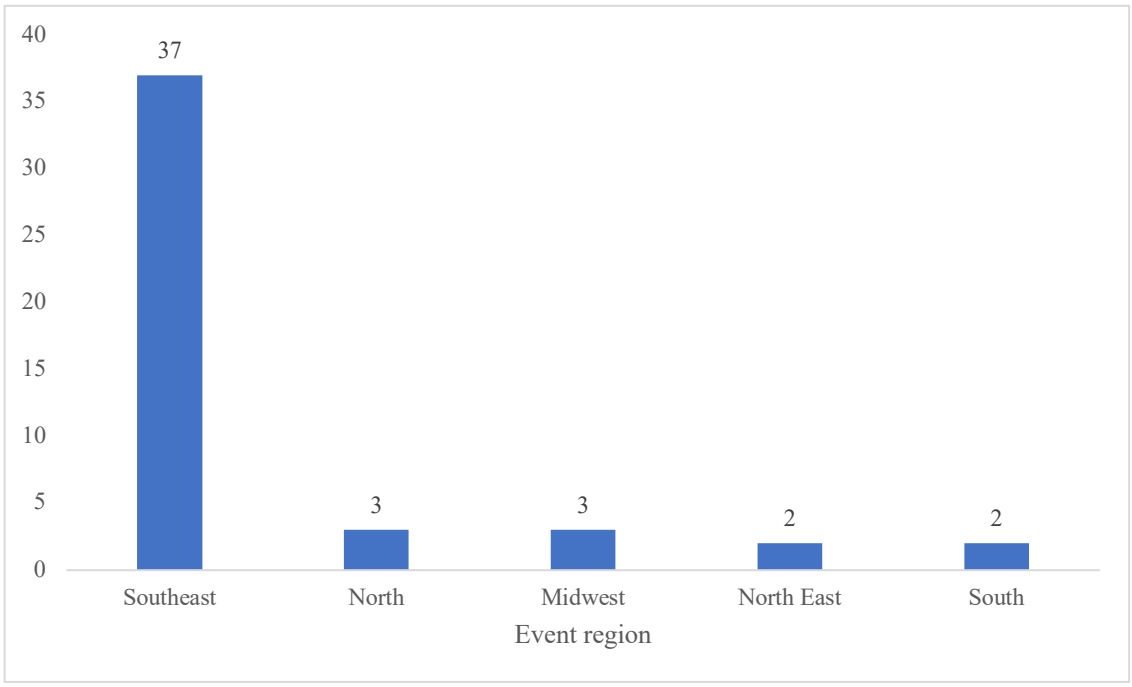
South region with three and the Northeast with only one Edition (XII of 2019), which took place in the city of Natal, capital city of Rio Grande do Norte state. In this case, only the Midwest and North were the only Brazilian regions that have not hosted any *ENPEC* Edition.

In this sense, there is a predominance of *ENPEC* events in the Southeast and South regions; this fact can be justified by *ABRAPEC* (the association responsible for organizing this event) being located in the State of Rio de Janeiro, which reinforces this prevalence of the event occurring in these regions.

Category 3: Research regions

The research region category consists of the region from which the research originates, and this information is captured through the affiliation of the main authors present in the works. Thus, it was possible to verify that the largest number of works came from the Southeast region, while the Center-West and Northeast were the regions with the lowest number of studies in the Art-Science axis (Figure 2).

Figure 2. Number of works by research region.



Source: The authors.

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The greater quantity of studies from the Southeast region can be justified, above all, because it is the main region in terms of hosting the event editions, which directly facilitates the logistics of researchers residing in the region. In addition, the largest number of universities and graduation programs are also found in this region, reinforcing this fact.

Category 4: Knowledge areas

The studies addressed the knowledge areas of Biological Sciences, Chemistry, Physics, and Mathematics. Works that exclusively contemplated one of these areas, and works that addressed the themes together, thus moving between two or more of the aforementioned areas in interdisciplinary proposals, were included. Interdisciplinarity is at the heart of the Art-Science axis, however, promoting actions in this context that unites different fields of scientific knowledge combined with the arts is promoting actions that engage individuals involved (Cachapuz, 2014), enable creativity and make studying Science funnier and meaningful (Duarte *et al*, 2018; Elias *et al*, 2019).

Still, there were works that did not specifically address any area of knowledge, but theoretically sought to discuss perspectives in relation to the Art-Science axis and its importance for science education in Brazil. Also, there were works along these approaches to report experiences at different education levels, as well as a survey of teacher and student conceptions on the subject, and research focusing on the approach of this axis in curricular proposals.

Art-Science approaches are valuable strategies that collaborate in a broad sense with scientific learning in the most diverse areas. In proposals for interventions in art-science that address specific science subjects, such as biology, physics and chemistry, or when approaching it in its broadest sense, as a “tool” for interpreting the world (Feitosa, 2021). Even on the school floor, in collaborative proposals, this axis promotes rapprochement between teachers of different sciences and their respective students, providing engagement and breaking down barriers (Cachapuz, 2014).

Category 5: Teaching level/modality

The works addressed different levels, stages, and teaching modalities. Thus, art and science were placed as components that contribute synergistically with teaching and learning in Kindergarten, Elementary School (early and final years), and High School, both in the regular modality and in Youth and Adult Education (YAE). It is worth highlighting that, regardless of the level of education, whether in early childhood education, primary or secondary education, it is possible and relevant to promote learning in Art-Science through a wide plurality of artistic manifestations. In fact, inserting art into the scientific context from the perspective of Art-Science stimulates students while evoking curiosity and artistic skills that they can use while learning science (Almeida *et al.*, 2019).

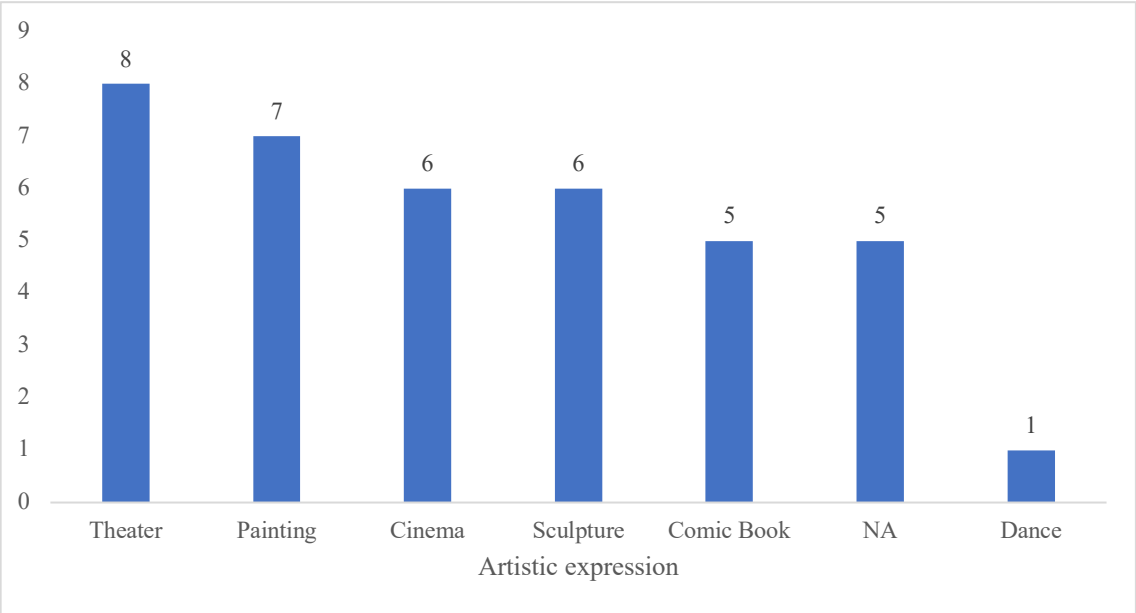
In addition to Basic Education, articles related to the topic were included at the level of Higher Education, Undergraduate and Postgraduate at the Master's Degree level. Thus, it is possible to establish that combining art with science and vice versa contributes to teaching and learning at various educational levels. It is worth noting that, at higher education levels, specifically in the initial teachers' training courses, it is of great importance for them to come in contact with the art-science axis during their undergraduate studies, so that they can integrate this perspective for future use in their professional activities. (Duarte *et al.*, 2018).

Moreover, it is noteworthy that there were works that did not specifically contemplate any level/modality due to the proposal. These specific works can be exemplified as literature reviews, textbook analysis, and analysis of audiovisual resources, among others.

Category 6: Artistic expression

A significant diversity of artistic expressions was observed in the analyzed articles (Figure 3), being contemplated by the more traditional arts such as theater, painting, and sculpture. Furthermore, it was also possible to observe productions containing more contemporary expressions combined with teaching and learning science, such as studies that used cyber art. It is noticeable that there were articles that used proposals containing more than one typology, for example, when using music and film productions as a resource in teaching proposals.

Figure 3. Number of artistic expressions included in the articles.



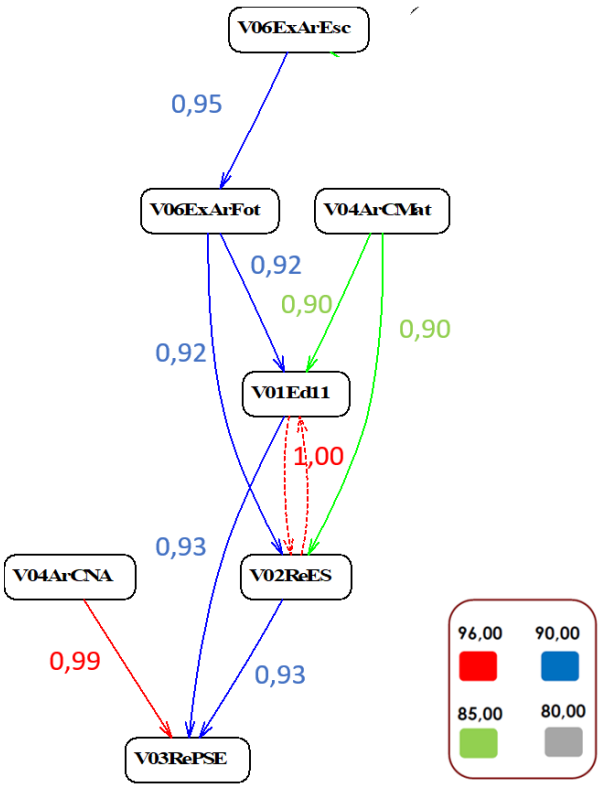
Source: The authors.

Works in this category did not use a specific artistic expression but contemplated the theme in a more theoretical way, or at least without delimiting and using some type of art in a practical way. Works that did not make practical use of artistic typologies are, for example, related to research studies of subjects' conceptions on the Art-Science axis. Therefore, it is important to highlight that studies that focus on investigating theoretical aspects of the art-science axis are essential, as they contribute to rethinking and implementing improvements in scientific education, even though this is not an easy task (CACHAPUZ, 2014).

Statistical Implicative Analysis (SIA)

At this point, we will verify the trend relationships observed between the analyzed variables through the implicative graphs generated by the CHIC software program. The implicative graphs make it possible to verify possible trend relationships between the variables, allowing us to visualize relationships of greater and lesser intensity between them (RÉGNIER; ANDRADE, 2020). The implicative indices used were 96, 90, 85, and 80 to verify the relationships of greater intensity and lesser intensity, respectively. In this sense, in Figure 4, we can observe the general implicative trends between the variables.

Figure 4. General implicative graph.



Source: The authors.

According to the graph above, it is possible to see some relationships with strong trends. We can highlight some aspects among these more intense

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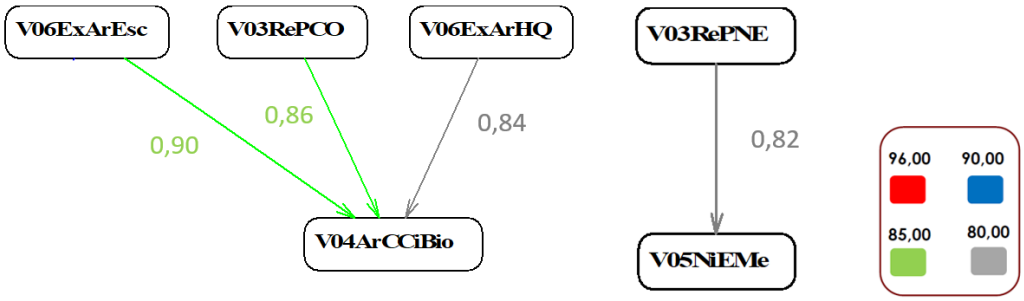
trends, such as the higher rate observed between Edition XI and the South Region of the Event (V01Ed11<=>V01ReES), in which studies published in Edition XI show a strong tendency to be from the South Region of the Event and vice versa. This is due to the fact that this Edition was based in the South region, so the information was already expected.

Another strong relationship is observed between the Artistic Expression of Sculpture and Photography (V06ExArEsc=>V06ExArFot), in which works that made use of sculptures have a strong tendency to use photographs, perhaps because photography serves as a physical record of the sculpture to be analyzed later. At a slightly lower intensity, it appears that there is a tendency for works that used Photographs to be published in Edition XI (V06ExArFot=>V01Ed11), as well as works from the Mathematics area also to come from this Edition (V04ArCMat=>V01Ed11). Most of the variables revolve around the XI Edition of the event.

Considering only the Artistic Expression, Research Region, Teaching Level, and Knowledge Area variables, it is noted that there is a tendency for works that used Sculptures to be in the Knowledge Area of Biological Sciences (V06ExArEsc=>V04ArCCiBio), as shown in Figure 5. This observation is relevant because many sculptures in museums, for example, represent the human figure or animal figures, which can lead to reflections on contents such as human anatomy. In this sense, the art illustrating and supporting anatomical studies has centuries of records, demonstrating that the Art-Science relationship in anatomy was of great relevance in the evolution of scientific knowledge about human anatomy (Janeiro; Pechula, 2016).

Figure 5. Implicative graph of the Artistic expression, Research region, Education level and Knowledge area variables.

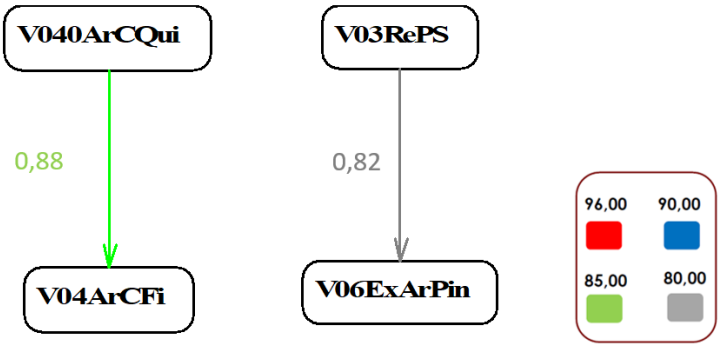


Source: The authors.

As less intense trends, we can highlight that the works that used comic books and the works that come from the Northeast Research Region show a lower tendency to be works performed with high school students (V06ExArHQ=>V05NiEMe and V03RePNE =>V05NiEMe). The use of comic books in teaching and learning processes is a good alternative to work with high school students, as they make use visual and linguistic resources that can be significant for knowledge construction processes, in addition to being a very attractive resource to this audience (Santos; Garcia, 2019).

Considering the knowledge Area, Research Region, and Artistic Expression variables (Figure 6), we can see that there is a tendency of works published in the Chemistry area also to - involve the physics area (V04ArCQui=>V04ArCFi). These trends are justified by the fact that such areas have been approached in an interdisciplinary way in the verified works, including a proposal of activities that contemplate different knowledge areas, adding to the Art-Science concatenation, and is a strategy that effectively contributes to science learning (Duarte *et al.*, 2019).

Figure 6. Implicative graph of the Artistic expression, Research region and Knowledge area variables.



Source: The authors.

To a lesser extent, works from the Southern Research Region tend to use Artistic Expression in Painting (V03RePS=>V06ExArPin), showing interest in the visual artistic aspect in collaboration with scientific training.

CONCLUSIONS

The Art-Science interface constitutes an abundant field for developing research in Science education. Furthermore, it comprises an axis that significantly contributes to teachers and students at different educational levels. This provides subsidies for planning and executing effective pedagogical strategies that combine the scientific field with artistic expressions to achieve educational goals.

The works at ENPEC, which dealt with the Art-Science axis, had a timid introduction, only being present in some of its editions, including having the first publication dated from the fourth edition of the event in 2003. The productions related to the theme contemplated strategies, proposals, knowledge areas, and artistic expressions with rich diversity, demonstrating that there are several possibilities to contemplate proposals in this line.

The Statistical Implicative Analysis enables the evidence of aspects in the studies that could hardly be verified only through descriptive statistics. Thus, linking these two statistical analysis methods raises more reflections and thereby enables new discussions considering the different science education areas.

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