ISSN 2178-2229

DOI: https://doi.org/10.18764/2178-2229v32n1e25384

"How was teachers' training with these scientific materials?": school knowledge, experience, and self-training in the city of São Paulo (1878-1931)

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Abstract: This text aims to present how teachers were trained in the natural sciences, primarily in the subject of Physics, using scientific materials (instruments, machinery, apparatus) through demonstration. The study is supported by Tardif's (2014) ideas, who considers the various paths taken by teachers to gain knowledge and establish a rational training process, whether through schooling or creative actions constituted throughout their professional experience. The text results from studies of documents and analysis of the bibliography pertinent to the history of science education in the city of São Paulo. This article shows that the training of teachers using scientific artifacts occurred through the mediation of instruments themselves, between theory and practice, highlighting the tacit and gestural knowledge fostered by textbooks, sales catalogs, and contact with the companies that built these materials.
Keywords: teacher training; physics teaching; history of science education; scientific artifacts.

1 Introduction

This article aims to find answers to the question at stake seeking to gather the knowledge produced by different studies, so as to have an empirical synthesis about the teaching practice of natural sciences, mainly Physics teaching. On one hand, it gradually wants to present the circulating knowledge about science and its teaching by studying the prescriptions in laws and rules as the canon used in schools. On the other hand, we follow the uses of materials, analyzing the didactic compositions presented in the curriculum, in the books, catalogues, and in the available scientific objects.

When talking about teacher training and knowledge, I was instantly reminded of the question in the title, who was posed to me years ago, since I decided to work with the materiality focused on the history of education in natural sciences. At that moment, I could raise a hypothesis on the subject. After ten years, with more support and different studies, we can

discuss teachers' knowledge and training more assertively, understanding teachers as public agents who sought knowledge on natural sciences and how to teach them.[1]

At that time, in a workshop held at *Universidade Federal de Minas Gerais*, in the *Núcleo de Pesquisas sobre a Educação dos Sentidos e das Sensibilidades* (NUPES/FAE/GEPHE), one of its members holding a scientific artifact and after much speculation with the workgroup, said: "We have no idea what this object is for ."It was a Gravesande's ring, an instrument used by Willem Jacob 's Gravesande in the 18th century to demonstrate the dilatations of bodies under heat. It was also a scientific artifact of the "historical" type because it delineates the public presentation of this invention. This material is found in different university and school archives in several continents. It carries a concept of science and an instrumental and technical history, registering a social and historical composition among experts and amateurs when studying calorimetry (Bocchi, 2020). There are local, global, and transnational stories about the circulation and use of this artifact. Nonetheless, during that workshop, it was a forgotten object, an "abandoned modernity" or "an old innovation". The study of artifacts and scientific materials is interesting because they are challenging and present us with many doubts. In the case of the study on Gravesande's ring, the question about how this artifact was used for teaching was asked because the function of that object was forgotten.

This article discusses teaching with scientific objects presenting different situations, in the Normal School or not, in which teachers sought knowledge to establish their professional practice and fulfill their role in natural sciences. Presenting knowledge based on the work with scientific artifacts demands recognizing the importance of studies on their instrumentation. The scientific instruments are mediators between the scientists and knowledge production, as they allow modeling the scientific experiment and data collection. Furthermore, the validation of experimental facts is contextual, showing the belief that what they produce is not universal but depends on social convincing. Therefore, audience expansion is important in science history and school multiplies this validation from demonstrative experiment (Braghini, 2017).

Hence, science is not only seeking "objectiveness and truth" but also a practice that produces social phenomena. Pestre (1996) affirms that science is less a system of statements and more " knowing how to do with", which means reinforcing abilities as elements as important as the formulation of theories, even showing that there is an interdependence

[1] The question was made by the then-student Leonardo Gomes (nowadays, a professor and researcher at IFMG), who Prof. Marcus Aurélio Taborda de Oliveira advised at the time, during a workshop on tridimensional documents, more precisely, scientific artifacts. This activity took place in the *Núcleo de Pesquisas sobre a Educação dos Sentidos e das Sensibilidades* (Nupes) within the *Grupo de Estudos e Pesquisas em História da Educação* (GEPHE), both in the School of Education in *Universidade Federal de Minas Gerais* (UFMG).

between both.[2] As we can see, the praxiological element – or, as Guijarro Mora (2018) says in the case of teaching with scientific artifacts, "tacit knowledge" – happens in the relationship of the teacher with the experience materials, through the mediation between content and theoretical materials.

We perceive here a triangle relationship of teaching, public power, and the companies selling these products. The question of the text is simple, and here lies the answer: How was teacher training through these artifacts? We studied the training process in this historical sense to question what grounds the values of a given time and which are the social, structural, and contextual forces that determine what should be teachers' knowledge. In the end, we stress teachers' achievements in their efforts for social recognition and establish the basis of what should be understood as science.

Methodologically, the article was thought with Maurice Tardif's (2014) theory of "teacher knowledge" in mind, considering "the thoughts, ideas, judgments, discourses, and arguments that obey certain rationality demands", that is, it seeks the logic thought and practiced by teachers, rationally, based on the knowledge and values dictated at the time, as well as the forms to implement the teachers' work portrayed in the documents. This author classifies knowledge into four types: professional education, disciplinary, curricular, and experienced (Tardif, 2014, p. 199). The author points out that these types of knowledge are integrated, emerging from diverse sources and following the process and the progress of teachers' professional life.

Therefore, the knowledge might emerge from early teacher training held in school; what is acquired in programs and didactic books; their own experience, the work practice, and task socialization using work tools (Tardif, 2014, p. 63). This means it is also possible to question teachers' knowledge through the history of acquisition and use of materials, as we are faced with an inquiry on the material conditions to obtain knowledge. The article also shows the relationship between teachers with their teaching material, though not ignoring other formative processes, precisely because they dialogue with varied forms of knowledge apprehension sought by teacher wanting to increase their knowledge, according to Tardif (2014).

The study is supported by documents, such as prescriptions, newspaper records– mainly Estado de S. Paulo – and the direct study of scientific material from the *Marista Arquidiocesano* School Museum [*Museu Escolar do Colégio Marista Arquidiocesano*]. The

[2] A scientific instrument is a device or tool used to take measures, make observations, or experiences in scientific studies. Therefore, it is important to point out that not all artifacts found in school collections are "scientific instruments." There are machines, full apparatuses, accessories, scientific toys, etc. Furthermore, in natural history collections, we see taxidermied animals, rocks, anatomic models, etc. Thus, in this article, we use the terms scientific artifacts or scientific material in general to refer to any object used in teaching a natural science. If necessary, we will use specifications through the name of the artifact or "scientific instrument" when it is really the case.

study space is the city of São Paulo, between 1878 and 1931, i.e., the period in which the discourses related to science and technique start to be connected to the recognition of Normal School as a training center and when new there are new contributions in the name of science marked by the recognition of school quality in the Francisco Campos Reform. The reform interference in science teaching is recognized, in this article, due to its evident intervention in schools' scientific spaces, mainly considering them as new criteria of educational quality considering natural sciences, in the equivalence processes to *Colégio Pedro II.*

The study relevance stands out due to the dialogue between History of Education and History of Science, thus, we present a brief discussion about this relationship. The text emphasizes that science and education should not be seen as different disciplinary fields but as areas that Interact and mutually influence each other throughout history. This relation is complex and e dynamic, reflecting a continuous dialogue between both areas that, in this study, traverses the history of professionalization and teaching knowledge.

2 **Historical Intersections:** Science and education in the constitution of teaching knowledge and the circulation of science instruments

Since the 19th century, science has gained legitimacy when involving the schooled public, who works as witnesses of scientific events. Schooling is not only a way to disseminate scientific knowledge but also a factor that validates and legitimizes science itself. Scientific parameters shape school education, and schools play a crucial role in the formation of a culture that recognizes science and technology as authorities in a decoding nature.

The schooling process is closely connected to the history of science, either through the dissemination of contents and experimental activities, such as prospection and school practice, or because the definition of school education itself is shaped by scientific parameters. School is responsible for creating a social process that recognizes science and technique as "true" decoders of Nature, granting them authority and legitimacy (Belhoste, 2012).

So, there is not necessarily a disconnection between the history of scientific education and the history of sciences. Science, as a result of social practices, depend on the connections between people and theories produced within an "institutionalization" process. School is one of these places, replicating the "scientific spirit" through experiences in the classroom.

There is a conversation between the areas, avoiding the delineation of epistemologic fronteirs when telling the history of Physics teachers in the city of São Paulo. This indicates a more dynamic historical complexity, before considering science and education as different disciplinary fields with insurmountable theoretical and practical hierarchies. Science and

education walk hand in hand in a history of dialogue that establishes the force of their own social representations.

Though there are differences between the spaces to make science and school, it is not the school's role to construct "scientific models". The replication of what science produces is not the only way to analyze the role of science teaching. Even when faced by epistemological differences, school cannot be excluded from the circuit that plans the ideas and representations of science. The school space validates the knowledge produced by scientists; it can reproduce a school culture convenient to the "didactic transposition of sciences" and is not foreign to the circuit of academic production (Belhoste, 2012; Chervel, 1990).

Tardif's (2014) idea that teachers' knowledge are integrated and emerge from different sources is related to how school validates and reproduces scientific knowledge. According to this researcher, teachers' rationality can be explored in the context of how teachers use their disciplinary and curriculum knowledge to teach, in this case, reflecting the interconnection between teachers' practices and the production of scientific knowledge.

Furthermore, it is clear for this author that there is a deep connection between the use of teaching materials and practical experimentation in the process of broadening the knowledge teachers produce and teach. This is connected to the discussion at hand, exactly because school is a space of experimentations that qualify the representations on science through the functions, uses, and symbols of physics' artifacts.

What is at stake is the association of these knowledge with the origins of the knowledge presented at school by the didactic material used and the experience which can (or not) be connected to self-teaching. Therefore, the social sources of acquiring these knowledge and methods of integration and socialization of the formative processes are diverse and, here, the intention is to present some of these forms.

The educational discourse incorporates techniques and technology to reduce geographical, knowledge, culture, and time distances. They are perceived as fundaments to several social utopias, but also emerge from major disasters and, at the time, by the terrors emerged with World War I (1914-1917). School and science are involved in this scenario as evident signs of modernization and innovation. Both are possibly the most relevant social technologies of what we call modernity.

In the scientific education trajectory, the educational institutions absorb techno-scientific values and knowledge, through the combination of interests generated by scientists, technicians, education renovators, artisans, a vast scientific market, commercial intermediaries, exhibitors, and teachers. Since the second half of the 19th century, we see an exaltation of technique and technology shown in world exhibitions, pedagogical and school museums, hundreds of purchase guides, etc. In question is the emergence of a technical civilization and a "morality of usefulness" manifested in different interpretations of life lessons and the

formation of a process of linear production economy that intertwines and advances in this sociopolitical and historical scenario. All these individuals share their opinions on the best materials and methods to teach science, highlighting the importance of using a broad array of technologies as essential components of experimental teaching through the practice of visual, demonstrative, replicable, and modeling teaching.

This technological myriad involved values and symbolic charges of progress and improvements can be seen in an example that starts with Oscar Thompson, who was then the director of São Paulo Public Instruction. In December 3, 1918, when the course of Public Hygiene held in the Escola Normal de São Paulo finished, he made a speech asking teachers and principals to disseminate scientific knowledge in favor of the hygienist cause. In this case, the discourse school is seen as a type of local safeguard to deal with diseases; a space to disseminate preventive means, indicating an experimental humanism based on the development of observation. In the second semester of that year, the "*grippe hespanhola*" [Spanish Flu] spread nationwide. Ferreira's (2023) work shows how schools started to present themselves as a hygienist institution. Several places in the state capital were converted into hospitals during the influenza pandemic that devastated the plant in 1918 and brought despair to the city of São Paulo.

Oscar Thompson reinforced teachers' appeal to science, stimulating the creation of school museums. According to Thompson, when organized by teachers and students together, the school museum "enriched by minerals and several species of our flora and fauna," would be one of the best teaching processes, raising the observation ability, making students able to classify and exercising on them the wish to know and study up close the usefulness of things (animals, plants, objects). In this speech, the teacher analyzed the knowledge presented by school museums, stimulating the collection of elements from Brazil because the museums are "full of foreign things that do not raise any interest in children."[3] His proposal indicates much information. One of them is the possibility of studying science through simple elements.

However, more than three decades previously, there was an appeal for São Paulo schools to purchase scientific materials. The Regulation of *Gymnasios* (1885) shows this concern in acquiring objects seeking the composition of school museums and laboratories. Each São Paulo gymnasium would be provided with a "Physics cabinet" (OESP, 1895), Chemistry laboratory, Natural History collections, library, and all the materials needed".[4]

The city's newspapers started to announce schools with their science gabinets, considering the attraction of new students. People donated pieces for the school museums,

[3] OESP, Sep. 03, 1918, p. 6.

[4] Regulamento dos Gymnasios, Articles 9, 10, 13 (1885).

as was the case of Alberto Leite, who donated to *Escola Neutralidade*[5] some scientific objects; schoool museums were bought and resold, as the one offered at Gusmões Street, nº 40, with new devices, complete, at a "reasonable price"; the scientific spaces were part of schools' advertisements, such as *Collegio Andrade* (women's section) and *Escola Neutralidade* (men's section), offering a "modern integral education" with Physics and Chemistry cabinets, museums, devices, instruments, and illustration maps.[6] In the city of São Paulo, since the 19th century, there are cases of teachers who used laboratories to conduct personal experiences, not only to give classes (Madi Filho, 2022). There are correspondences between teachers and places that produced and commercialized scientific instruments, including the discussion about class plans. There are catalogs from manufacturers used as didactic material, as we will see later (Alcântara; Palma, 2023).

Meloni and Alcântara (2019) focus their analysis in the history of scientific didactic materials in the state, presenting an intra and extra school approach, indicating the triangular relationships between school, government, and the market that produced materials to show that the interaction between the public and the private worlds shaped the increase of scientific knowledge in that period. The authors also followed the idea of materials practical use emphasizing that the Regulation of the then *Ginásio Nacional* (1901) presented itself as a way to shape science teaching and the *Escola Normal de São Paulo* as one of the main teacher training centers, following this movement.

However, public schools were not alone in this dynamic of providing laboratories with materials for science teaching. Private schools also followed this path of acquiring scientific materials. There are various science collections in these establishments in the capital (Arquidiocesano, São Luís, Dante Alighieri, N. Sra. da Glória, among others). In *Colégio Marista Arquidiocesano*'s case, the institution emphasizes science's importance in education, connecting it to faith.

This approach was seen as a way to modernize school, while keeping the traditional Catholic values. The school acquired a long list of scientific materials since the mid-19th century. These acquisitions were part of a strategic movement to affirm their educational quality. Such objects were used to teach Calorimetry, Galvanism, Pneumatics, Electricity, Hydrostatics, Optics, Mechanics, and Astronomy. The collection comprises machines, apparatus, models, accessories, scientific toys, and "historical" instruments (Braghini; Pedro; Piñas, 2014). The school's museum, Physics cabinet, and laboratory were complimented by the federal inspectors in the early 1930s, when it went through a second equivalence process to *Colégio Pedro II*, for example. The school's laboratories and museum stood out in the doc-

[5] A Província de S.Paulo, Dec.08,1887, p. 2.

[6] O Estado de S.Paulo, Feb.14,1893, p. 3; Oct. 06, 1885, p. 2.

uments of school assessment in 1933 due to the presentation of pre-established models for the sake of school quality, from determinations done by the equivalence processes provided by the *Francisco Campos Reform*. That is, the equipped school must obligatorily have specific spaces to teach the subjects of Chemistry (experimental amphitheater with laboratory), Physics (cabinet), Natural History (school museum) (Pedro, 2014).

The curiosity about possible means of acquiring knowledge to teach through these materials is renewed, considering the generalization of how they gradually join the circuit of schools in the city of São Paulo. Next, we see some examples of how the training with these artifacts could occur, considering the idea Tardiff (2014) indicated about school formation and experimental and tacit knowledge.

3 Education of new Physics teachers in *Escola Normal de São Paulo*

Before considering the formalized education in schools, we have to speculate about the circumstances for public experimentation in the city of São Paulo, and this point needs more studies. About the open circulation of scientific materials, we have, for instance, that in 19th century Paris, there were more than 500 chemistry laboratories throughout the city. They were housed in institutions that dealt with this practice, such as drugstores and academies, but half of them were in households.[7] In the case of Paris, these actions are perceived within a movement to increase experimentation that starts from the aristocratic guard to popular curiosity. We need to understand that, at first, the scientific practices were in the hands of some aristocratic and extravagant personalities; later, they became a widespread curiosity and the engine of economic and moral progress to build nations. This popular curiosity cannot be dismissed because the fabrication of these products was progressively open to quench this desire (Belmar García, 2017).

This is not an empty speculation because the knowledge emerged from experiences are discussed in different spaces and means of communication throughout Europe and America. That is, clubs, associations, scientific societies, places to meet, discuss, and check this knowledge do not appear as bodies that see themselves as scientific but that become scientific through a process. This transposition of scientific knowledge into demonstration showed the public what could be done with these experiences and was highly successful at the end of the 18th century, moving to the 19th century. Science popularization could be seen

[7] We cannot ignore women's chemistry work in the domestic spaces. There are studies about women who developed chemistry from the experience of "home economics," considering food. There is also women's relationship connected to their Chemist husbands as lab partners and technicians. The integration of chemistry in everyday life is also connected to women through domestic chemistry education, through entertainment or education itself (Páez; Garritz, 2013; Baldinato; Porto, 2009; Fyfe, 2004). The process of chemistry professionalization and women's progressive erasure from Brazil's history is undoubtedly an interesting object of analysis.

in studies that recorded these actions in squares, circuses, concert halls, etc. We know that experimental demonstrations were extremely popular (Nieto-Galan, 2011; Lehman; Bensaude-Vincent, 2007) at the time.

Vergara (2008), discussing the context of Rio de Janeiro in the 19th century, points out the different ways used to present science, in the "popularization" sense. First, through periodical publication: scientific magazines and journals focused on the general public, not only for specialists, such as *La Nature* and *Journal des Voyages*, besides books of scientific vulgarization, that is, works that sought to translate scientific results into a language accessible to the laic public. We witness the creation of societies and congresses that promoted the discussion and the dissemination of scientific knowledge, working towards its popularization. Finally, there were public lectures and exhibitions aiming the interaction between scientists and the public, allowing an involving communication of scientific advancements (Vergara, 2008, p. 7). In this sense, we see a specific environment to expand scientific knowledge that matches Tardif's (2014) perspective when affirming the possibility of increasing knowledge from part of the teachers through printed materials and varied knowledge that circulated in the lived context.

A reported example of this action in São Paulo shows that the public was willing to spend one hour and a half listening and watching the demonstration of a new device experimentally tested. Dr. Ennes de Souza, presented as an illustrious teacher in Rio de Janeiro, demonstrated in the *Escola Polytechnica* how a bumper he created worked.[8] He said that the invention had been used in several occasions – in trains, ships, and elevators – and called upon students to perfect his invention because it "interests every Brazilian". After the experience was over, his words were welcomed with "frantic applause" (OESP, 1909, p. 3).

The experience demonstration is a teaching practice present in the Physics and Chemistry classes of *Escola Normal de São Paulo* because many documents point out the need to present these types of machinery in classes or auditoriums of different European schools. This was also the case of this São Paulo institution. However, we need to see it as an integral part of a long history of science that permeates the aristocratic saloons, a practice popularized in the domestic environment, a way to disseminate science to broaden the audience and become a teaching didactic. The demonstration classes work not only as an efficient teaching method but also start representing a common and recognized way to disseminate knowledge. They play a crucial role in the education of future teachers and

[8] Antônio Ennes de Sousa was born in São Luís do Maranhão, in May 6, 1848. He was a member of the Brazilian Science Academy, the Zurick Natural Science Society, in Switzerland, and the Berlin Chemistry Society, in Germany. He was a notorious scholar in Mineralogy. About Maranhão, he wrote: *Discurso sobre a organização da biblioteca popular do Maranhão* (1871), *Relatório da exposição maranhense de 1871* (Acc.. *Souza, Antônio Ennes de. Dep. fed. Maranhão* (1871); *Pres. Sociedade Nacional de Agricultura* (1897). CPDOC.

in science validation, when broadening its reach and recognition between different groups (Braghini, 2017).

This school was the São Paulo center of training *per excellence*, considered as a mechanism to construct the citizen that shapes technological development. As João Batista Pereira, president of the São Paulo province, states: "School prepares the citizens, it shapes hearts and characters, and they receive elementary instruction that adapts them to the achievements of the industrial world and for the great affections of intelligence [...]" (Pereira, 1878 *apud* Céfalo, 2022, p. 51). In a ceremony to certify teachers (1903), the class' s honored teacher, Oscar Thompson, in his ode to this public school says: "Instruct and educate because they teach to contemplate Nature, the source of all science. Observing its immutable and harmonious laws strengthens even more the faith on the Creator's magnificence" (OESP, 1903, p. 2).[9]

According to Meloni and Alcântara (2019), it was possible to identify among the remaining heritage objects of this school, two categories of scientific objects: utilitarian and specific ones. The first objects were used in daily laboratory procedures, while the former in more complex activities, mostly manipulable and followed by guidelines about the use of the objects presented in the teaching manuals with vast illustrations, showing the gestures and the performance the teacher should do.

In the 19th century, scientific devices could have the following roles: research and mediation instruments, teaching instruments during demonstrations, professional instruments, machines, models, and Physics instruments for entertainment (Brenni, 1997, p. 742). These objects were permeated by the idea of "natural magic," connected to the occult, and, in this way, seek to call attention to the observation of the phenomena (Van Helden; Hankins, 1994, p. 4).

Céfalo (2022) shows that the school auditorium was between the Physics cabinet and the school museum; the analysis of the built heritage indicates that this experimentation theater is the heart of the school. The same researcher points out the inexistence of subjects connected to natural sciences in the two first phases of the *Escola Normal de São Paulo*, between 1846-1878, indicating the emergence of the chair "French, Physics, and Chemistry" registered in 1880, in the so-called third phase of school working, under the perspective of republican aspirations.

For this reason, the author focuses the analysis on how this chair worked under teachers Paulo Bourroul (1880-1884), who graduated in Medicine in Belgium (1879), and later Aristides Franco Meirelles (1884) – also a Medicine graduate –, followed by Cypriano José de Carvalho (1884-1888), civil engineer and, finally, by José Eduardo de Macedo Soares (1888-1918), a physician graduated in the Medicine School in Rio de Janeiro. As we

[9] O Estado de S. Paulo, 01/12/1903, p. 2.

can see, teacher training in the *Escola Normal* has the prerogative of continuing the careers of technicians and scientists as teachers, showing the institutional interconnections resulting in scientific nets.

Alcântara, Meloni, Cardoso (2022) also find this when showing that the first teachers of natural sciences in several schools in the state were recruited from different areas, such as pharmacy and medicine, indicating a strong connection between scientific professions and education. This practice suggests that social and professional networks influenced faculty constitution, when hiring individuals that already had a solid scientific formation. Therefore, we see that *Escola Normal* should be understood from an entanglement of other institutions that developed professional science and public experimentation in the city, as part of a conglomerate of public instruction, from which the *Museu Paulista*, the *Escola Politécnica*, the *Instituto Butantã*, the *Instituto Biológico*, and the *Hospício dos Alienados* stand out(Céfalo, 2022).

Paulo Bourroul, for example, had a refined education: graduating in medicine, as said, in Brussels Medicine School. He was a physician in São Paulo and was nominated principal of the *Escola Normal de São Paulo*, while working as a teacher of the 5th chair, being the first person responsible to teach these subjects. Thus, he is recognized as the state official who assumed the responsibility of managing the resources for this knowledge, acquiring books, and several scientific objects, acting as a link in the dissemination of natural sciences and promoting the understanding of experimental methods.

Céfalo (2022) indicates that the bibliography grants a pioneering place to Prof. Bourroul, but it was Prof. Macedo Soares that, in fact, organized the scientific subjects, teaching them for 30 years. We can perceive the globalization of a specialized professional science and establishes itself as an essential need.

Observing the curriculum programs adopted, the contents show the following training for the Normal student: Physics, barology, hydrostatics, hydrodynamics, acoustics, thermology, optics, and electricity. For Chemistry: organic and inorganic chemistry studies highlight chemical compositions and industrial and agricultural processes. Since 1904, mechanics have been inserted into the study of physics, emphasizing cinematics and the work of industrial machines.

By observing students' final exams, we can perceive the emphasis given to experiences and the workings of such artifacts in the demonstration classes, with experiments for pure observation, operation, and application, which should be evaluated in oral and written tests. There is a profusion of action verbs, mainly "apply", "experiment", and "demonstrate" (Céfalo, 2022, p. 331-332). This follows what is presented by the didactic books, in which we can see that the classes demanded observation; resulting in an excessive number of il-

lustrations of hands operating machines, devices, instruments, and a wide array of scientific objects (Braghini, 2017a; Céfalo, 2022).

Regarding the need to acquire the teaching materials for the chair, the initial role of Paulo Bourroul stands out. This movement to purchase material focuses on the history of teaching, the history of the need for scientific products, and the trips of specialists and the objects as carriers of pedagogical innovations (Céfalo, 2022; Meloni; Alcântara 2019).

It is important to reiterate that the artifacts used in the school labs were not understood as didactic resources, that is, what simply intermediates theoretical and practical knowledge as an operational component. Themselves, their respective roles, and constitutive parts were described as contents, as part of the study program, and with science concepts inserted in their respective designs. The complexity of the devices had their own didactic charge (Guijarro Mora, 2018; Braghini, 2017a).

At the end of the 19th century, certain types of devices were frequently used in science cabinets aiming to understand their function: percussion devices, objects to demonstrate laws, among others, were studied for themselves and, not necessarily with the single purpose of observing what a natural phenomenon could cause. The French schoolbooks portrayed demonstration devices, which were often copies of "historical instruments", describing how they worked and connecting the phenomenon to be observed to the knowledge of the machine (Hulin, 2008, p. 96).

This is the same case perceived by Céfalo (2022), when indicating the existence of clear connections between the chair's didactic books, such as *Physique et Chimie* from Edmond-Jean Langlebert and *Leçons élémentaires de chimie moderne* from Charles Adolphe Wurtz, and the vast collection of teaching objects in the school cabinets. These objects include substances, glassware, and laboratory equipment (such as copper stills, Bunsen burners, stoneware crucibles, iron gas stoves, gas torches, and others), besides instruments, machinery, and implements used to teach Barology, Hydrostatics, Pneumatics, Acoustics, Thermology, Optics, and Electrology.[10]

The experimental character of the Physics classes conducted in *Escola Normal de São Paulo* can be seen by the notes of a class in April 11, 1912. They are written down in the study notebook of the student Norberto de Almeida, who presented his understanding about the Ramsden[11] machine or the experience of an electric tram. In the case of the Ramsden machine, the student understands the description of the machine and how it captures ener-

[10] About the teaching of electricity in the state of São Paulo, see: Gonçalves, Bruno Bianchi Lopes. *O ensino de eletricidade no estado de São Paulo (1890-1930): concepções, prescrições e objetos científicos*. Master's in Education. Pontifícia Universidade Católica de São Paulo, 2020.

[11] The Ramsden machine is an electrostatic device created by Jesse Ramsden in 1766. It is used to generate static electricity through friction.

gy triggered by force “including muscular” one, recording the production of electric current the machine produces. About the tram experience, which was a “scientific toy”, the students shows its triggering phases, pointing out the demonstration itself and the gradual movement progress (Almeida, 1902, p. 784-785 *apud* Céfalo, 2022).

As it was part of the artifact – the corporal condition to be enacted in its operation –, we see that the understanding process demands theoretical knowledge, taken from the books. However, as we will see, we have, respectively, the case of a company that sold scientific materials teaching a teacher how to make these devices work. Later, we understand how a teacher used a sales catalogue as a practical didactic manual. In both cases, we see creative forms of self-education in which the way of doing things depend on an action conditioned by the involvement with artifacts and the use of synthesis that, quickly, position teachers’ knowledge within what is, according to their criteria, important to be taught.

4 Teachers and knowledge channels: scientific materials and companies’ catalogs

In the literature on history of education, the use of the book “Primary Object Lessons”, from Norman Allison Calkins (1886)[12] as a teacher training method is well-known. It stands out by prioritizing the reasoning that allows scientific creation. In the case of sciences, when using the Lesson of Things, this manual works as an exemplary model focusing on the importance of observation and experience to form ideas, seeking to develop students’ judgment ability. This manual is a famous formative element for understanding science as the articulated portrayal of the fundamentals of the intuitive teaching method, education of the senses, and observation as a fundamental teaching process. The “*A Eschola Publica*” also stands out as a compilation of articles that seek to guide the pedagogical practices but focus on the curriculum guidelines and teacher training (Valdemarin, 2020). Both played a crucial role in disseminating new pedagogical practices in the creation of scientific culture, delineating how sciences should be taught in the early 20th century, with interpretations legitimated by groups that give them an authorial base and are recognized as subjects with educational interests.[13]

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[12] The original title of the book in English is *Primary object lessons for training the senses and developing the faculties of children*. In Brazil, it was entitled *Primeiras lições de coisas: manual de ensino elementar para uso dos paes e professores*, translated by Rui Barbosa, in 1886.

[13] The method “Primeiras Lições de Coisas” by N. A. Calkins was defended in the government by the then-representative Rui Barbosa through a long report to the Decree nº 7.247, from April 19 (BRASIL, 1879), which regulates primary and secondary education in Rio de Janeiro, followed by its translation. The report is called “Reforma do Ensino Primário” (1883) and we can say that this set of actions delineates the authority with which this manual gained power in Brazil as a guiding element of the reforms in Brazilian public instruction. The eleven volumes of”A Eschola Publica” are compiled in the book “Ensaio de Pedagogia Prática” as a

Another crucial document to observe the innovation of scientific knowledge, materialized in objects, refers to the sales catalogs of scientific artifacts circulating in several regions of the world that highlight various possible materials for teachers to use in class. The catalogues show the producer's perspective about the objectives of the materials offered for sale, establish new knowledge standards about "precision", "objectiveness", and "observation", introduce new sensibilities and limit representations and several social values in the name of science. This material allows the debate on one of the existing connections between the school and the scientific environment. We see that some teachers used them not only to see the and buy the products, which would be its main objective. In this case, the catalogs became reliable sources to validate scientific knowledge about the objects' functions and the teaching content.

Guijarro Mora's (2018) work warns on the standardization offered by these manufactures regarding teachers' behavior. During the process of acquiring materials, the author shows the dynamic operation of this equipment arrival in the teaching institutes in Spain, as well as the appropriation forms created by teachers. There are two associated analysis dimensions that allow us to analyze the relationship of teachers with these sales' catalogues.

The first dimension shows the teaching models presented by manufacturers, considering the communication paths between the producer and the consumer of product transit. A part of this knowledge starts from the material provider, so as to show its control regarding their uses. There is the intention of a sale, indicating actions that might interest teaching at a theoretical and procedural level besides registering pieces and prices. Both show the manufacturer's direct participation and the indirect participation of agents and sales representatives, to guide the adequate knowledge to teach sciences.

Alcântara and Palma (2024) tell us the case of teacher Epiphanio Maria, identified as the vice-rector of *Gymnasio Nossa Senhora do Carmo*, with Max Kohl, a German manufacturer of scientific materials. A letter from February 2,1927, shows the answer the company gave to the Physics and Chemistry teacher. The company Max Kohl is sorry that the teacher could not work with the Odstrci equipment. This device is used to demonstrate the Coulomb Law, one of the pillars of electrostatics, demonstrating the interaction force between two punctual charges at rest. It explores the idea of attraction and repulsion forces and loads of opposite and equal signs, respectively.

According to Alcântara and Palma (2024), this teacher asked the shipping of *Zeitschrift* für den *Physikalische nund chemischen Unterricht* (Physics and Chemistry Teaching Journal) to consult it about how to use the device, following the object's assembling instructions and its use. In the reply, the company prefers to briefly presente the device indicating its

fundamental initiative of São Paulo pedagogical press as a training landmark established by the reform led by Gabriel Prestes (1892) (Valdemarin, 2020, p. 1036).

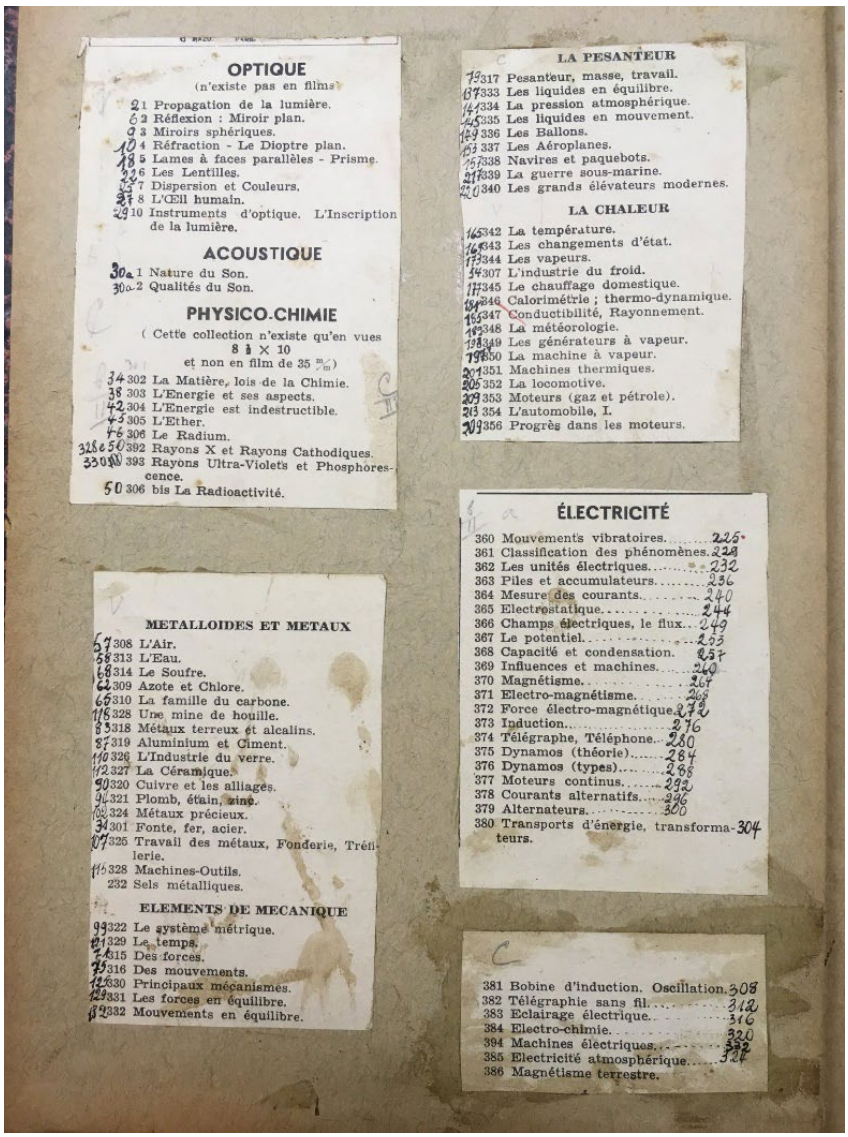
work and functions with an illustration. According to the researchers, this could be a possible company intervention, which would have cut the illustration of the device from its own catalog to show the teacher its operation phases.

The authors point out some hypotheses about the reasons for the teacher's request. Perhaps he intended to receive the complete journal, what did not happen, but there are references that this description was taken from this teaching journal. The teacher might have pointed out doubts simply to receive the journal in Brazil. However, this case is interesting to show that this type of contact existed. It portrays the "ways of doing" from the company to the teacher. This episode widens the pathways teachers take to seek knowledge for their classes.

The second dimension considers the procedures to acquire products and how teachers relate to these devices, reflecting the appropriation of these materials. In this case, the teachers show diversified interests in acquiring material and appropriating and assimilating the published content. Such actions highlight that they are guided by specific proposals connected to their work condition, developing practices of teacher experience, their particular perceptions about what should or should not be taught, and how they should be taught.

In the case of a non-identified teacher from *Colégio Arquidiocesano*, he transformed a catalog from *Casa Mazo* into a type of didactic guide. The commercial house Mazo was created in 1892 to sell different types of materials, from domestic devices and school materials, among them compasses, microscopes, sheet music, wall charts, etc. It stood out as a trader of optic devices, mainly photo and projection equipment. In this case, the catalog was transformed into a guide for classes, a practical manual. Based on it, between clippings, notes, and pages written in ink, we see the relationship of the teacher with the explanations dictated by the company. These traces foment the idea that the teacher dialogued with this material to organize the classes and broaden his knowledge. In the catalog's index, we can see that the teacher made his own marking in numbers (Figure 1) to alter indicate the pages in his own sequence (Figure 2).

Figure 1 – Catalog Mazo. Colégio Marista Arquidiocesano.



Source: Memorial do Colégio Marista Arquidiocesano de São Paulo (Catálogo Mazzo).

Figure 2 – Paging of catalog Mazzo.

Source: Museu Escola do Colégio Marista Arquidiocesano de São Paulo (Catálogo Mazzo, detalhe).

Through the catalogue index (Figure 1), we understand that the teacher valued the summarized content, in a practical and simple way. The catalogue's content show an abbreviated version of this set of knowledge with clear definitions and no major scientific proselytes. An example is what is presented regarding electricity, starting with basic concepts (classification of phenomena), and progressing towards more advanced ones (transformers' operation). In the study of electricity, we are presented with fundamental concepts (vibratory movements, electrical units, electrostatics etc.); applications that can be thought of in a practical way, such as the themes of batteries, accumulation, current measure, etc.; theoretical aspects, like the study of electrical cables, condensation, potential, capacity; studies on electromagnetism, which expands the knowledge of interconnected areas, for instance, physics. Finally, we find the study of scientific devices whose uses depend on electricity, delineating the era of infrastructure technologies (batteries, accumulators, dynamos, transformers, telephone, telegraphs, etc.). All these types of knowledge are presented in a clear and synthetic way.

In the case of the experiment presentation, there was a shock between what was common sense knowledge, called magical, and the one considered "scientific." The instrument, as the mediator and enabler of senses, helps organize scientific knowledge from the instrumental keys provided by science itself (Halleux, 1991).

We end up with the perception of another notable characteristic, when the technology representation is presented by these teachings as elements of the industry they mirrored. For legislators and individuals in the political sphere, technology was also associated with the promotion of economic growth through the stimulus of industry, an allegory of civilization. For the teachers, it was a resource that simplified the understanding and the embodiment

of theoretical concepts while showing, in a practical way, the activity and the operation of the material used, as in a performative game. De La Lastra and Guijarro Mora (2012), two very active researcher on the use of these objects for teaching, wonder about students' impressions during the impact of these manipulations, because it was probably an object that worked as an interruption in the theoretical explanation and that, occasionally, provokes some emotion or surprise. It is an element connected to emotions and, therefore, not irrelevant.

4 Final remarks

Maurice Tardif (2014) explores how teachers broaden their knowledge through different sources and experiences. The author highlights that teaching knowledge is theoretical, practical, and contextual. These types of knowledge are acquired through initial training, practical experience in the classroom, the interaction with colleagues and students, and self-education. He emphasizes that teachers continually build their knowledge, adapting themselves to the changes and surprises of the school environment. He also states the importance of tacit knowledge, which is implicit knowledge acquired through practice and reflection on one's own experience. Teachers' professional development involves acquiring new knowledge and integrating and practically implementing these types of knowledge in the school routine. Related to these ideas, this article seeks to summarize how teachers in the turn of the 19th century, in the city of São Paulo, educated themselves and acquired knowledge when dealing with the scientific artifacts at their disposal.

The research shows that the training of natural science teachers was marked by a diversity of knowledge, including those emerging from the subject, the curriculum, and the practical experience, even self-teaching, following Tardif's (2014) classification. These types of knowledge are fundamental for teachers' practice and reflect the complexity of the educational work.

Even though there was no State investment to provide scientific materials to all schools, there were schools that excelled, as is the case of the Normal School inventory, showing that the acquisition of scientific material for teacher education was related to a broad circuit formed by the State, the market, and the schools.

The didactic books, training manuals, catalogs, and, mainly, the scientific artifacts were identified as essential tools in teacher training because they not only transmitted theoretical knowledge but also promoted a practical and contextualized understanding of sciences. To a great extent, the presented science didactic books indicate this concern of mixing theoretical types of knowledge, presenting a practical knowledge regarding a craft knowledge, marked on the artifacts as a gestural undertaking, established as a technolog-

ical project. The study of didactic materials, such as books and catalogs, reveals that the contents were presented in a practical and accessible way, allowing teachers to build applicable knowledge in the classroom. The progression from basic concepts to more advanced one in electricity is an example.

The article shows that, in the training of teachers for these subjects, theory and practice are inseparable. Regarding theory, there was content in the didactic books and the mastering of exhibiting and describing the objects and their respective functional aspects. As practice elements, the Physics subject highlighted here shows the mastery of specific know-how but that was not distinguished from the theoretical knowledge of the content privileged in the didactic books, which could also be acquired and used by other channels of knowledge. We highlight a public-private relationship in the access to knowledge permeated the interference of companies that produced scientific materials.

The article discusses how technique and technology were seen as intruments of modernization and innovation, questioning that the interpretations about natural science teaching involve questions of legitimacy and authority that, in the case, are seen in the composition of *Escola Normal* classes and the use of companies' catalogues as didactic manuals, what caused different levels of credibility granted to the prescriptions in the progressive struggle of natural sciences to establish themselves in the curriculum. In the end, we see that training teachers for Physics was an inseparable process of self-education, while the sales catalogs worked as a creative resource. The interaction with these materials promoted contextualized and applied knowledge, reflecting the rational logic over the construction of teachers' knowledge, which emerged from diverse experiences and interactions in the educational environment.

At the end, this article proposes a dialogue between two areas of academic knowledge, trying to show that, through cultural history, perhaps there were no such frontiers. It points out the precursor sign of more consolidated dialogues to understand the solid relations between science and school since the 19th century.

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Received in June 2024 | Approved in January 2025

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