

PAPER

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Shedding synchrotron light on teacher training

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Abstract

This paper aims to introduce the initiative *Escola Sirius para Professores do Ensino Médio* (ESPEM, Sirius School for High School Teachers) hosted by the *Centro Nacional de Pesquisa em Energia e Materiais* (CNPEM, Brazilian Center for Research in Energy and Materials) and supported by the *Sociedade Brasileira de Física* (SBF, Brazilian Physical Society). The program covers the principles and applications of synchrotron radiation with expositive lectures, discussions, and visits to the CNPEM facilities. By using semi structured interviews, a remote focal group and surveys to find out the impact of ESPEM, we observed that the teachers shared their experience and disseminate the acquired knowledge with their peers and students.

Keywords: synchrotron light, in-service training, professional-development schools, high school teachers

1. Introduction

A basic education teacher, when motivated and encouraged to do quality work, is able to reach a diverse audience and to be a multiplying agent of knowledge and content, in an incalculable way. In large and often unequal countries in terms of social issues and educational opportunities, this

motivation and incentive must come from partnerships between research and educational institutions, at the national level, which play a key role in motivation and incentive to teachers

There is a growing gap between basic science and people's perception and knowledge about science, and this setback needs to be slowed down with encouragement in all spheres of education. At a time when there is a return to negationism and a lack of credibility in relation to science,

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in an international political context unfavourable to the scientific community, SBF and CNPEM jointly decided to assemble a team of researchers, to conceive strategies to bring together the cutting-edge science produced by Brazilian researchers in Brazil to high school teachers. Inspired by similar initiatives [1–4], both institutions were interested in preparing a professional development course [5] for high school teachers. At the same time, the largest scientific infrastructure built in Brazil, Sirius, was in its final construction stage, so it was the perfect timing to create the *Escola Sirius para Professores do Ensino Médio* (ESPEM, Sirius School for High School Teachers).

CNPEM is a private non-profit organization under the supervision of the Brazilian Ministry of Science, Technology, and Innovations (MCTI). Located in the city of Campinas-Brazil, CNPEM is the institution responsible for designing, building and operating Sirius, which is an electron storage ring dedicated to the production of 4th generation synchrotron light. Synchrotron light is an intense, coherent, collimated and broad-spectrum electromagnetic radiation, ranging from infrared to hard x-rays. Such radiation is generated whenever the electron beam path is bent by magnetic fields in the particle accelerators [6].

In the context of the need to value Brazilian science, in order to bring together and present to the community that is outside academic knowledge, that Brazil is a producer of cutting-edge science and technology, ESPEM was created. One of the objectives, in addition to making this approximation, between society, school and the scientific community, is to alleviate the great geographical inequality and academic opportunities that exist in this continental country, and for this reason, the ESPEM organizing committee decided to hold a course that reached to the whole country.

In Brazil, professional development courses for teachers, which last between 20 h and 80 h, are categorized under the name of continued education courses [5]. This definition agrees with that of Villegas-Reimers [5], which explains the importance of teacher training courses when they are in the classroom. ESPEM lasts 40 h (Monday–Friday), and participating teachers stay for 1 week immersed in theoretical classes, conducting experimental visits and attending lectures followed by informal conversations about

proposals for applying concepts of modern physics in basic education.

In the next section, we present ESPEM. Section 3 presents the results of the research carried out with the data collected from the participating teachers, in order to discuss the dissemination in the whole country that was motivated by the professional development course. Finally, some conclusions are drawn.

2. Sirius school for high school teachers (ESPEM)

At the beginning of 2018 the process of structuring and organizing the course for teachers began. Researchers from different areas of activity were invited to be part of the organizing committee. One of the researchers is a physics teacher at high schools in the city of Rio de Janeiro, and a doctoral student in the field of physics teaching at the *Universidade Federal do Rio de Janeiro* (UFRJ), being the first author of this work. He attended the entire course as a participant observer, and maintained contact with all participants after each edition. Physics researchers from *Universidade Federal do Rio de Janeiro* and *Universidade Federal do Rio Grande do Sul* were also invited to join this group, in addition to researchers from CNPEM. The first edition took place in January 2019, between the 14th and the 18th, as shown in figure 2. Twenty places were available for this first school, and participants were chosen among the more than 200 applications of physics teachers from all over the country, including 16 states and the Capital. With the success of the first edition, the organizing institutions increased the number of places to 35 in the following edition, which took place between 20th and 24th January 2020, as shown in figure 3. Teachers from 20 states, in addition to the capital, were selected.

The course was designed so that it would collaborate to reduce social inequalities and opportunities in Physics teaching. Therefore, for the selection of teachers, some contexts were considered such as regionalization, since Brazil is a very large country and at the same time very unequal, in which certain regions receive greater financial and academic incentives than others. Another subject that was considered was the gender balance of those selected, as there is a

great need to encourage more women interested in science. A third concern was to privilege teachers who have fewer professional opportunities. In Brazil, high schools can be divided into federal education, private education or state/municipal education. Teachers at state/municipal schools have fewer opportunities due to various historical and social issues in the country. Figure 1 shows the relative numbers in the two editions.

The selected teachers had a large part of their costs, such as travel expenses, food and lodging, funded by the organizing institutions, which is rather uncommon in Brazil.

The participating teachers remained immersed in the laboratory complex for a week, attending theoretical classes on contents of modern and contemporary physics such as: particle accelerators, synchrotron light production, x-ray optics, detectors, some basic concepts of experimental techniques such as scattering and diffraction, spectroscopy, among others. In addition to visiting the laboratories and attending lectures and presentations by the researchers, as we can see in table 1, they met to develop pedagogical strategies to present the concepts studied in school education, such as: circular movement, oscillatory movements, electromagnetism, special relativity, quantum theory and radiation interaction with matter [6].

CNPEM operates four national laboratories, international references in cutting-edge research: Laboratório Nacional de Luz Síncrotron (LNLS, Brazilian Synchrotron Light Laboratory), Laboratório Nacional de Biotecnologia (LNBio, Brazilian Biosciences National Laboratory), Laboratório Nacional de Biorrenováveis (LNBR, Brazilian Biorenewables National Laboratory) and Laboratório Nacional de Nanotecnologia (LNNano, Brazilian Nanotechnology National Laboratory) [7].

In addition to learning the contents of modern physics and the principles of particle accelerators, teachers met at specific times during the course to develop strategies on how to use that knowledge in high schools. At each visit to the laboratories, there were conversations between teachers and researchers, for the application of the concepts in basic education. This is perceived in a report by a professor from the northern region who participated in 2019: ‘In my class planning, for example, I always include this topic about particle

accelerators, when I talk about certain subjects. When I talk about optics, I remember the monochromator issue a lot because it caught my attention. How it is manipulated, how they manage to manipulate the energy range and the light range they want to use ... When I go to talk about electrons, for example—I start talking about electrons for third year students. When we go deeper into the theme of electricity—which I always start by talking about atoms—I rescue this issue from atomic models ... I always talk about the movement of this electron very close to the speed of light to generate all this radiation, which is used by the particle accelerator.’ (Literal translation from Portuguese).

The selection criteria were: to be a teacher in service; and to demonstrate some experience in scientific outreach; a letter of interest explaining why they wanted to participate in ESPEM; and a letter of intent presenting proposals for the activities they would develop after returning to their cities, if selected.

After completing the course, the teachers returned to their cities with the mission of being the ambassadors and disseminators of Sirius and of CNPEM research in their community. That includes not only making presentations to their students, but seeking funding to popularize and disseminate science. The next section presents the activities performed by the 55 participant teachers after ESPEM.

3. Results of ESPEM

A communication channel was created to monitor the activities carried out by the teachers after returning to their home towns. In addition to this channel, some interviews and questionnaires were conducted, and a focus group was set up, where open questions were asked. The activities carried out after the professional development course were compared with the information collected during ESPEM. We have also compared the resulting activities with those proposed before the course, analysing the letters of intention and motivation that the teachers sent with the school application.

One of our goals is to understand how ESPEM interfered, motivating each participating teacher to continue their training after the course, or to participate in the training of other teachers.

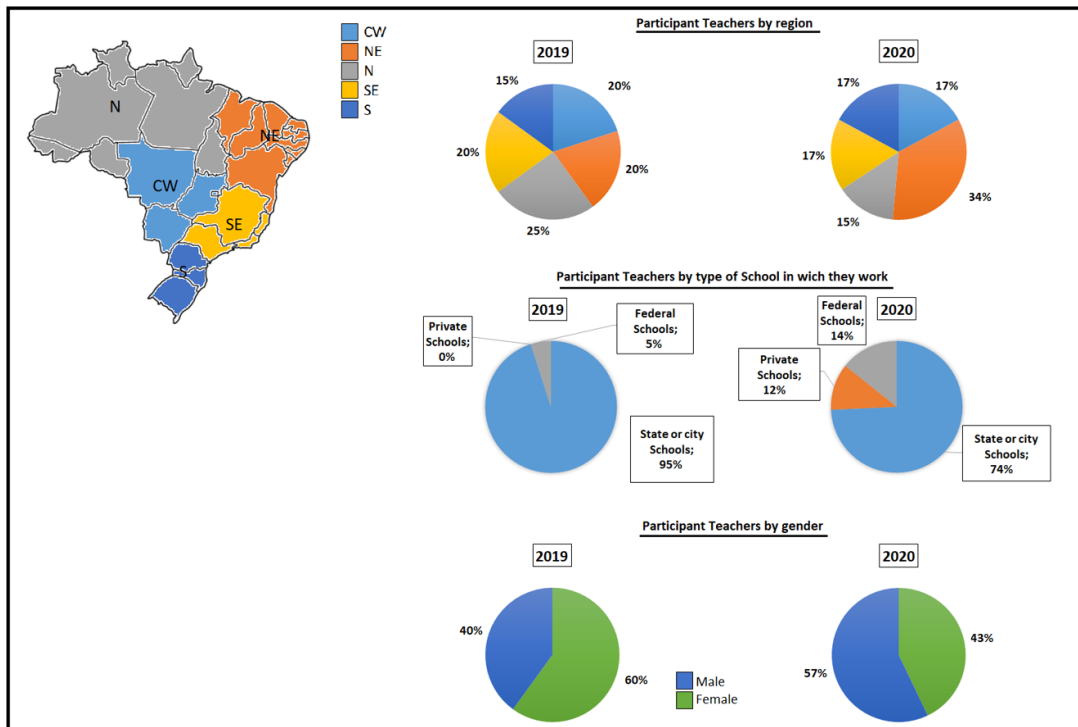


Figure 1. Participants teachers by region, gender and type of schools, and year.

Table 1. ESPEM schedule.

Schedule	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	Introduction to ESPEM	Class 1: electromagnetic radiation	Lesson 3: synchrotron light	Lesson 4: spectroscopy	Lesson 6: imaging
Morning	Introduction to CNPEM	Lesson 2: particle accelerators	Workshop didactics 1	Lesson 5: diffraction	Workshop didactics 2
Morning	Introduction to Sirius				
Lunch					
In the afternoon	Introduction and visit to LNNano	Introduction and visit to LNBio	Introduction and visit to LNBR	Visit to UVX	Visit to Sirius
In the afternoon	Seminars researchers at LNNano	Seminars researchers at LNBio	Seminars researchers at LNBR	Seminars researchers at LNLS	Seminars researchers at LNLS
In the afternoon	Participating teachers' mini presentations				
In the afternoon	Seminars researchers at LNNano	Seminars researchers at LNBio	Seminars researchers at LNBR	Seminars researchers at LNLS	Seminars researchers at LNLS



Figure 2. Twenty teachers participating in the 1st edition in 2019 with a speaker and one of the authors and members of the organizing committee.



Figure 3. Thirty-five teachers participating in the 2nd edition in 2020 with one of the authors and a member of the organizing committee.

All 55 teachers were interviewed and commented on the stimulus in their teaching career promoted by ESPEM, as shown in table 2.

In each region of Brazil, there are different types of opportunities for teachers, some with many courses and others with almost none. The figures in table 2 show data in which some teachers have taken more than one course. We had cases of teachers who took up to four of these activities, such as mini courses,

continuing education courses, joined the Master's degree and collaborated in other teacher training courses.

As one of the main actions of teachers was to disseminate the acquired knowledge in their cities, data were collected on the performance of these teachers in their community. Participating teachers were instructed to record all activities carried out in their community on the dissemination of

Table 2. Follow-up activities developed by the participant teachers by region (first column) of Brazil.

Region	Mini courses (under 20 h)	In-service training (with 20 h or more)	Master courses started after ESPEM	PhD courses started after ESPEM	Collaborated in teacher training courses after ESPEM
Central West	6	4	2	1	4
Northeast	8	11	3	2	7
North	6	6	1	1	2
Southeast	7	1	1	0	3
South	8	3	1	2	3
Brazil	35	25	8	6	19

research conducted at Sirius and at CNPEM laboratories.

Table 3 presents a comparison between the numbers of high school students, university students, high school teachers and the number of people outside school and university environments who attended lectures and presentations by ESPEM participating teachers after the course, by region. For the sake of comparison, table 3 also presents the Human Development Index (HDI) by region.

From table 2, one can see that 35 teachers attended mini short courses to continue their training, and improve class preparation and the production of materials for their students. Twenty-five have taken other continuing education courses (courses of more than 20 h in duration), acknowledging that they were motivated by the participation in ESPEM. They also stated their wish to continue preparing themselves to provide a better themselves as teachers. As for the change of professional career planning, 14 have begun graduate programs (master's and doctoral courses), and confirmed that the contact with cutting-edge research, motivated them to follow new professional paths. In addition, 19 teachers collaborated in some extent in continuing education courses to peers in their community, arguing that as they had the opportunity to participate in ESPEM, they had the desire to share with other professionals who did not have that opportunity.

Moreover, from table 3 one can see that with 'only' 55 participant teachers, it was possible to reach 14 390 high school students, 1466 college students and 827 teachers. As for the case of the general public, table 3 shows an impressive

number about 22 000, even though the majority of that was due to science channel created by just one of the ESPEM participants, with over 19 000 views by the time this research was performed.

Most of the teachers reported that their professional life, in relation to the planning of their classroom and the contacts with other teachers from different realities, were the biggest impacts for their participation in ESPEM, according to the testimony of two teachers below.

All participants from both editions have access to an online storage cloud with materials to assist in organizing their activities. Teachers held regular classes, held lectures at their educational institutions, organized scientific events in places with many people such as Public squares and shopping malls. Many virtual lectures were held. The participating teachers could contact some members of the organizing committee, to ask questions about the issues discussed during the school. We can see, in the report of two teachers, the importance of participation in the Synchrotron School, as a teacher who participated in 2020, commented:

'Well, the Synchrotron School for High School Teachers, in fact, is an opportunity for us teachers to have access to an excellent research centre. And we understand that ...it is an opportunity, for us teachers in the field, to have a continuous, targeted education, making links with the practical world of cutting-edge research. Nobody would like to let this opportunity pass, would they? I think that any teacher who has access to a week immersed there, learning about content that we spend on a daily basis in the classroom and that we explain, but we would love to see

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Table 3. Number of high school students, university students, teachers and the general public that attended presentations by teachers by region of Brazil.

Region	Dissemination after the training 2019/2020					HDI
	Number of teachers	Dissemination to high schools	Dissemination to colleges	Dissemination to teachers	Dissemination to general audience	
CW	10	1400	0	72	50	0.757
NE	16	4061	175	280	200	0.663
N	10	5810	980	415	21 847	0.667
SE	10	1390	121	40	0	0.766
S	9	1729	190	20	110	0.754
Brazil	55	14 390	1466	827	22 207	0.727

practical applications, and very in-depth research on the topic ... So, the school served as a watershed for the vast majority of all teachers there, because most had a very clear experience in the classroom with high school. We had an experience of dealing with this audience, but this enrichment of what we lived there helped us a lot on a daily basis. This link with the Sirius School was very positive.’ (Literal translation from Portuguese)

A teacher, who participated in 2019, related what was seen in the continuing education course with his pedagogical practices:

‘ESPEM put us in contact with teachers from various states, with situations totally different from ours. So, what we thought was a problem, we realized that many other teachers from other places solved it, gave solutions to the same or similar problems, with a creative option, using elements of more practice in the classroom, using the few resources that they had to encourage ... So, we managed to take advantage of this experience of others to understand our problems in our schools and communities. Mainly, for those who deal with the public school. And we can understand the problem, find solutions and have someone to share with. Because now we already have the experience of others who went through the experience and some were successful, others unsuccessful, but this exchange of experience helped us to understand our situation in our city, in our community, and to be able to act more effectively.’

An important point to be considered is that the two regions that have the lowest HDI (see table 3), were the ones with the highest numbers

of dissemination events. It is clear that teachers in the poorest regions were the most motivated to disseminate scientific knowledge. This fact alone would already establish the success of ESPEM, which was designed to reduce regional inequalities in science dissemination and teaching.

4. Conclusions and discussion of results

In a context of the need for continuing education for teachers across Brazil, and the need to bring cutting-edge research and basic education closer together, a professional development course was created in the largest science laboratory complex in Brazil and a new source of light Brazilian synchrotron, Sirius. Seeking the greatest balance in the selection of teachers, this course was held in two editions and aimed to present the science and technology produced in Brazil by Brazilians, so that participating teachers, in addition to learning certain physics concepts, pass it on in their cities, for his high school students, higher education, his fellow teachers and the general public.

Teachers stated that the ESPEM provided an opportunity to meet peers from others regions and to exchange teaching experiences. It was also an opportunity to get in contact with researchers and to learn about the state of art in physics. They were not aware that a structure such as SIRIUS was available in Brazil. The follow up activities developed by the teachers, disseminating what they learned at ESPEM were able to reach a large number of students and peers alike, as well as the general public. Looking ahead, we plan to extend the next ESPEM to other science teachers, such

as chemistry and biology. We hope that ESPEM will continue to provide inspiration for science teachers and help to bring science to close the gap between basic science and the public. The figures in table 3 clearly demonstrate the multiplicative potential of initiatives such as ESPEM in disseminating scientific awareness and motivating high school teachers, particularly in the less developed and remote areas of large and heterogeneous countries such as Brazil. We believe similar initiatives would be equally successful in other developing countries.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgments

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All participant subjects are above 21 years old, gave their image consent, and agreed to participate in this research. This work was carried out according to the principles described in the journal's ethical policy and informed consent for publication was obtained from all participants.

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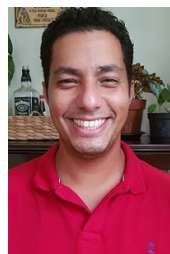
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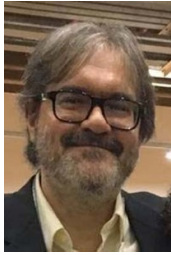


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