Shedding synchrotron light on teacher training

V Acioly\textsuperscript{1,2,\textdagger}, T Paiva\textsuperscript{2}, G Azevedo\textsuperscript{3}, T Rocha\textsuperscript{4}, R Picoreti\textsuperscript{5} and A C F Santos\textsuperscript{1,2,\textdagger}

\textsuperscript{1} PEMAT, Universidade Federal do Rio de Janeiro, PO Box 68530, Rio de Janeiro, RJ CEP 21941-909, Brazil
\textsuperscript{2} Instituto de Física, Universidade Federal do Rio de Janeiro, PO Box 68528, Rio de Janeiro, RJ CEP 21941-972, Brazil
\textsuperscript{3} Instituto de Física, Universidade Federal do Rio Grande do Sul, PO Box 15051, Porto Alegre, RS CEP 91501-970, Brazil
\textsuperscript{4} Laboratório Nacional de Luz Síncrotron (LNLS), Centro Nacional de Pesquisa em Energia e Materiais (CNPEM), Campinas, São Paulo CEP 13083-970, Brazil
\textsuperscript{5} Centro Nacional de Pesquisa em Energia e Materiais (CNPEM), Campinas, São Paulo CEP 13083-970, Brazil

E-mail: vitoracioly@gmail.com

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,
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, build-
ing 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 gener-
ated 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 know-
ledge, that Brazil is a producer of cutting-edge sci-
ence and technology, ESPEM was created. One of
the objectives, in addition to making this approxi-
imation, 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 edu-
cation 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, con-
ducting experimental visits and attending lect-
ures followed by informal conversations about
proposals for applying concepts of modern phys-
ics in basic education.

In the next section, we present ESPEM.
Section 3 presents the results of the research car-
ried out with the data collected from the partici-
pat ing teachers, in order to discuss the dissemina-
tion 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 structur-
ing 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 doc-
toral 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 Fed-
eral 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 col-
laborate to reduce social inequalities and oppor-
tunities in Physics teaching. Therefore, for the
selection of teachers, some contexts were con-
sidered 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 Biociências (LNBio, Brazilian Biosciences National Laboratory), Laboratório Nacional de Biorrenováveis (LNBio, 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.
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                        | Workshop didactics 1                         | Lesson 5: diffraction                       | Workshop didactics 2                         |                                               |
| Morning    | Introduction to Sirius                       | Lesson 2: particle accelerators              |                                               |                                               |                                               |
| 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 | Seminars researchers at LNBio             | Seminars researchers at LNBR              | Seminars researchers at LNLS                | Seminars researchers at LNLS                |                                               |
| In the afternoon | Participating teachers’ mini presentations |                                               |                                               |                                               |                                               |

Figure 1. Participants teachers by region, gender and type of schools, and year.
Shedding synchrotron light on teacher training

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
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
ESPEM 2020 was funded by MCTI with resources from the project Ciência na Escola (Science at School). V Acioly thanks to the Sociedade Brasileira de Física and the Centro Nacional de Pesquisa em Energia e Materiais for supporting the creation of the Escola Sirius para Professores do Ensino Médio (ESPEM, Sirius School for High School teachers), and support for doctoral research in Physical Education and Physics Teaching carried out by the Universidade Federal do Rio de Janeiro. The Brazilian Center for Research in Energy and Materials (CNPEM) is a private non-profit organization under the supervision of the Brazilian Ministry of Science, Technology, and Innovations (MCTI).

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.

ORCID iDs
V Acioly  @ https://orcid.org/0000-0001-6655-5920
A C F Santos  @ https://orcid.org/0000-0001-7402-6594

References
[1] Alexopoulos A, Pavlidou M and Cherouvis S 2019 ‘Playing with protons’: a training course for primary school teachers at CERN Phys. Educ. 54 015013
[2] Pavlidou M and Lazzeroni C 2016 Particle physics for primary schools—enthusing future physicists Phys. Educ. 51 054003
[3] Wiener J, Woiithe J, Brown A and Jende K 2016 Introducing the LHC in the classroom: an overview of education resources available Phys. Educ. 51 035001
[4] Sinflorio D A, Fonseca P, Coelho L F S and Santos A C F 2006 Teaching electromagnetism to high-school students using particle accelerators Phys. Educ. 41 539
[5] Villegas-Reimers E 2003 Teacher Professional Development: An International Review of the Literature (Paris: International Institute for Educational Planning)
[6] Acioly V, Picoreti R, Rocha T C, Azevedo G D M and Santos A C F 2020 A luz sincrotron iluminando a formação de professores A Física na Escola 18 (http://www1.fisica.org.br/fne/phocadownload/Vol18-Num2/FNE-18-2-200607.pdf)
[7] CNPEM website (available at: http://cnpem.br/) (Accessed 5 December 2020)

Vitor Acioly is a high school physics teacher and a PhD candidate in physics teaching at UFRJ, specializing in teaching modern and contemporary physics, teacher training and scientific dissemination of science laboratories for students, teachers and the general public.

Theresia Paiva is a condensed matter physicist and co-director of Tem Menina no Circuito, an outreach program to bring girls to STEM. She is a professor of physics at UFRJ.

Received 5 January 2021, in final form 18 February 2021
Accepted for publication 1 March 2021
https://doi.org/10.1088/1361-6552/abeac6
Shedding synchrotron light on teacher training

Gustavo Azevedo is professor of physics at UFRGS, specialized in materials science and synchrotron radiation-based techniques.

Tulio C R Rocha is a researcher at the Brazilian Synchrotron Light Laboratory (LNLS) of the Brazilian Center for Research on Energy and Materials (CNPEM). He is a specialist in physics of materials and soft X-ray spectroscopy.

Renan Picoreti has a PhD in physics and currently works in communications and outreach at the Brazilian Center for Research in Energy and Materials.

Antonio Santos is professor of physics at UFRJ and specializes in atomic and molecular physics and physics education research.