HISTORY OF MUSIC, ELECTROMAGNETISM AND THE SUN: AN INNOVATIVE EDUCATIONAL RESOURCE FOR PRE-SERVICE PRIMARY SCHOOL TEACHERS

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Abstract

In general, science education programs for pre-service primary teachers encounter several challenges, including inadequate subject matter training and uninspiring lectures. This results in a disconnection between university learning and real-school experiences. To address these issues, an innovative science teaching course for primary school teachers is proposed. This course emphasizes interdisciplinarity, practical activities and didactical resources, with the ultimate goal of breaking the cycle of unmotivated and unskilled students by producing competent and enthusiastic science teachers. The course structure, implemented at the University of La Laguna, creatively blends experimental sciences, history, music, and maths through engaging methods and practical activities. The integration of simple demonstrations and interdisciplinary approaches has had a positive impact on the pre-service teachers. As a result, they are now better equipped to design innovative educational resources for future primary students and have gained confidence in their abilities to teach science.

Keywords: science education, primary school, innovation, interdisciplinary.

HISTORIA DE LA MÚSICA, EL ELECTROMAGNETISMO Y EL SOL: UN RECURSO EDUCATIVO INNOVADOR PARA PROFESORES DE PRIMARIA EN FORMACIÓN

Resumen

En general, los programas de educación científica para profesores de primaria en activo se enfrentan a varios retos, como una formación inadecuada en la materia y unas clases poco estimulantes. El resultado es una desconexión entre el aprendizaje universitario y las experiencias en la escuela real. Para abordar estos problemas, se propone un curso innovador de enseñanza de las ciencias para profesores de primaria. Este curso hace hincapié en la interdisciplinariedad, las actividades prácticas y los recursos didácticos, con el objetivo último de romper el ciclo de estudiantes desmotivados y poco cualificados mediante la formación de profesores de ciencias competentes y entusiastas. La estructura del curso, implantado en la Universidad de La Laguna, mezcla de forma creativa las ciencias experimentales, la historia, la música y las matemáticas mediante métodos atractivos y actividades prácticas. La integración de demostraciones sencillas y enfoques interdisciplinarios ha tenido un impacto positivo en los profesores en formación. Como resultado, ahora están mejor preparados para diseñar recursos educativos innovadores para los futuros alumnos de primaria y han ganado confianza en sus capacidades para enseñar ciencias.

Palabras clave: enseñanza de las ciencias, escuela primaria, innovación, interdisciplinariedad.

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1. INTRODUCTION

There is a vicious circle in science education that is difficult to break: poorly motivated yet skilled elementary and secondary students end up becoming teachers, still unmotivated when it comes to scientific areas, resulting in new generations of poorly motivated and skilled students and so on. It is of paramount importance to improve the skills of pre-service teachers, particularly in primary school education, to engage, motivate and educate new generations of scientifically educated citizens. Pre-service teacher programs at universities face long-standing issues (Bransford *et al.*, 1999; De Juana Oliva, del Pozo, and Ballesteros, 2016):

- Prospective primary teachers receive inadequate subject matter (content knowledge) training, while prospective secondary teachers lack knowledge about the nature of learning (pedagogical knowledge).
- Teacher preparation methods courses often rely on uninspiring lectures that fail to motivate prospective teachers.
- Prospective teachers are not introduced to research on teaching and learning.
- Disconnection between what pre-service teachers learn at universities and what they encounter in schools.
- There is not logical connection between the different courses that are offered in these programs.
- In-service teachers often perceive their initial formation as poor in both pedagogical and scientific content.

There exists an extensive body of scientific literature, courses, and online resources aimed at addressing these challenges, particularly on enhancing the initial training of teachers through innovative and engaging science teaching courses. To gain a comprehensive understanding of how such courses could be effectively implemented, we can seek insights from an AI application like ChatGPT (https://chat.openai.com/). These applications comb through vast databases to probabilistically identify the best possible matches for the given prompt.

In this sense, we used the following prompt: "Could you design the structure of an innovative course in science didactics for prospective primary school teachers, spanning 8 weeks and accommodating 130 students with limited science background? The course should emphasize the development of competences, interdisciplinarity, practical activities, the integration of new technologies, and evaluation methodologies with a gender perspective". The response (see Table 1) represents an average of the application's findings, offering valuable insights into implementing an innovative science teaching course for primary education. However, despite the intention of these courses to guide prospective teachers on how

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TABLE 1. STRUCTURE OF A SCIENCE TEACHING COURSE IMPLEMENTED THROUGH CHATGPT		
WEEK	LEARNING UNIT	CONTENTS
1	Introduction to Science Didactics and Competence-Based Learning	– Understanding the role of science education in primary schools – Introduction to competency-based learning and its importance in modern education – Identifying core competences in science education and their alignment with curriculum standards
2	Interdisciplinarity in Science Teaching	– Exploring the benefits of interdisciplinary approaches in science education – Designing interdisciplinary lesson plans and activities – Collaborative projects across subjects to enhance students' understanding of scientific concepts
3	Hands-on practical activities in Science Education	– Importance of practical activities in engaging students and fostering scientific inquiry – Designing and implementing hands-on experiments and demonstrations – Incorporating inquiry-based learning in science lessons
4	Integrating new technologies in Science Teaching	– Utilizing educational technology to enhance science learning – Introduction to virtual labs, simulations, and educational apps for science education – Creating interactive and multimedia-rich learning experiences
5	Assessment and Evaluation in Science Education	– Formative and summative assessment strategies in science teaching – Designing authentic assessments to evaluate students' scientific skills and knowledge – Addressing diverse learning styles and abilities through varied evaluation methodologies
6	Applying a Gender Perspective in Science Teaching	– Understanding the gender gap in STEM education and its implications – Strategies for promoting gender equity in science classrooms – Analyzing and selecting gender-inclusive teaching materials and resources
7	Project-Based Learning in Science Education	– Introduction to project-based learning (PBL) and its benefits – Collaborative project design that integrates various science concepts – Implementing and managing PBL in the primary school setting
8	Culminating Project and Reflection	– Students develop and present their own innovative science lesson plans – Reflecting on the course learnings and experiences – Sharing best practices and future plans for science education in their teaching careers

to organize their science teaching process, they themselves are often not structured in accordance with the principles they teach.

In this work, we present the strategy devised at the Faculty of Education of the University of La Laguna, Tenerife, to introduce pre-service primary school teachers to an innovative and interdisciplinary approach to learn and teach scientific thinking and science concepts. We divided a one-semester course on primary education science into 8 learning blocks, each containing a basic scientific idea and a teaching strategy to explain it. One of the blocks, which we will detail below to illustrate the working principles of our methodology, combines physics, history of music and the sun to create an engaging yet rigorous set of demonstrations. These demonstrations explain the basics of electromagnetism and its impact on our everyday life, particularly on the origin of many of the most popular music styles of the 20th and 21st centuries.

2. METHODOLOGY

All in-service primary school teachers in the Canary Islands (and the rest of Spain) graduate with a degree in Primary School Education. Many of the core subjects in this degree are common not only to the Spanish higher education system, but also to the European Higher Education Area (EHEA). In this sense, an efficient strategy to provide in-service teachers with innovative tools and skills in science education consists in training and inspiring them while being pre-service teachers. However, the implementation of these innovative programs will depend, to a large extent, on the academic profile of these students. In our case, the profile was established from a set of anonymous questions that were answered by 250 prospective primary school teachers during the 2019-2020 and 2020-2021 academic years. Only 4 questions of the survey were analysed, those related to the teaching/learning of science. First, it was asked the last year they took physics, chemistry, biology, and/or geology in secondary education. Roughly 70% of the students, regardless of their gender, did not take science subjects in high school. This implies that a significant portion of these pre-service teachers possess a limited, conceptual, and non-quantitative understanding of many of the basic scientific contents. This same profile has been found in other regions of Spain (Greca *et al.*, 2017; Verdugo, 2017) and in many other countries (Correia and Baptista, 2021).

The second question was about the grades obtained in secondary education scientific subjects. In a grading scale from 1 to 10, only 7% of these students got 9 or higher. An average grade, for all pre-high school scientific subjects, of 6.5 was obtained by the students that did not attend any science-related subject in high school, whereas this grading goes up to 7.8 when these students attended high school scientific subjects.

The third question was about their experience in secondary and primary education with science. Only 20% of the students are satisfied with the teaching received, whereas 50% of them think that it was mostly theoretical and 60% missed practical and manipulative activities. The fourth question analysed their attitude towards science: 81% of the students said they like science, while only 9% dislike it. Regardless of their attitude, 19% of the students confirm that they have difficulty understanding science.

In short, the most common profile for a pre-service primary school teacher at the University of La Laguna, corresponds to students with a pre-high school level in science and an academic performance of 6.5 out of 10. They have a positive

TABLE 2. STRUCTURE OF THE UNDERGRADUATE COURSE ON EXPERIMENTAL SCIENCE TEACHING		
LEARNING BLOCK	TEACHING STRATEGY	CONCEPT
I. Energy and matter	ICT	Natural phenomena
II. Transformations	Games	Geological strata
III. Measurements	Outdoor activities	Sun and Earth
IV. Electromagnetism	Demonstrations and storytelling	Sun
V. Chemical changes	Practical work in schools	Everyday life
VI. Heat	Demonstrations and storytelling	Candles
VII. Waves	Science museums	Natural phenomena
VIII. Dynamics	Lectures and demonstrations	Simple machines

attitude towards science and demand more practical and manipulative activities, that were absent during their secondary school years.

With this academic profile, one might think that more scientific content is needed to reduce the deficiencies the pre-service teachers have. However, we think that these students should acquire a global vision about the content and procedures of science through a different organization of the science educative content, one that goes beyond the common subject-based teaching/learning method. This alternative strategy, as presented in the Big Ideas of Science (Harlen, 2010), consists of a set of basic ideas connecting principles and phenomena that allow students understand the world around them and make informed decisions. We expect that the pre-service teachers will pass to their future primary school students the ideas and procedures behind this strategy.

The undergraduate program on Primary School Education at the University of La Laguna contains only two one-semester subjects related to the learning and teaching of science. One of these subjects relates to life sciences, whereas the second one relates to experimental sciences. We chose this second subject to implement our innovative strategy. In this sense, the subject was divided into 8 one-week-long learning blocks (see Table 2). Each block connects to a big idea in science and it is presented through a particular teaching/learning strategy (games, lectures, demonstrations, storytelling...) and a natural phenomenom. In many instances, the learning block goes beyond one particular matter, as in blocks I (STEM), III (Science and History), IV (Science, Maths and History of Music) and VI (Science and History), allowing prospective teachers to analyze whether a standards-based integrated curriculum is more beneficial in developing professional competencies than a traditional course-oriented curriculum (Kim *et al.*, 2004). History and History of Science are found in most of the integrated learning blocks, since it has been shown that they can lead to a better understanding of school science and put it into a social context (Solomon *et al.*, 1992; Fouad *et al.*, 2015; Seroglou and Koumaras, 2001).

The Sun serves as the central focus of study in two of the learning blocks. In block III, the prospective teachers delve into the significance of measurements in science through a collaborative project with primary school students. This project involves calculating the size of our planet, following the same experiment conducted by Eratosthenes in the fourth century BC. In block IV, that will be explained in detail, the pre-service teachers learn to make the interdisciplinary connection between our star and modern music through electromagnetism. In this sense, the pre-service teachers will learn to use non-curricular concepts in primary education (like electromagnetism) as an engaging and motivating didactical resource.

The idea of using the Sun to learn about electromagnetism has been exploited by different educational projects associated to space missions, like the Solar Dynamics Observatory spacecraft (SDO). This is a scientific and technological program to analyze the generation, storage and release of the solar magnetic field and its influence on Earth (Pesnell, Thompson, and Chamberlin, 2012). SDO provides a wealth of didactic resources (Drobnes *et al.*, 2012) based on current educational research. It integrates inquiry in the teaching/learning process, addresses misconceptions and perceptions towards science and scientists, and relies on extensive evaluation. Besides all these resources, there are many educational and outreach projects related to SDO, as well as projects related to many other scientific and technological concepts and ideas in astronomy and space exploration; among them: CosmoLab[1], Segway[2], NASA Wavelength[3], the Stanford Solar Center[4], SunTrek[5] or the European Space Agency[6]. These collections cover both formal and informal education, different instructional strategies and different audiences (students, families, professional development, etc.). Many align with national curricula and have been tested and evaluated.

The educational potential of the electromagnetic connection between the Sun and the Earth goes beyond the more classical approach, *i.e.* the explanations about the seasons, day-night, eclipses, moon phases, tides, climate, life, etc. (Frède, 2008). In this sense, the Sun becomes a motivating educational resource for pre-service primary school teachers, rather than part of the curriculum content.

In block IV, we designed a modified version of the Big Ideas of Science, where every branch of physics is explained through a basic global idea. In this framework, the big idea consists in defining electromagnetic phenomena as the result of the interaction between electrical charges, motion and magnetism: electrical charges in motion in an electrical conductor induces a magnetic field; moreover, a magnetic field moving relative to an electric conductor (coil) causes the motion of electrical charges (through the induction of an electromotive force) and finally, charged particles moving through a magnetic field experience a force (the Lorentz

1 See https://www.iac.es/cosmolab.
2 See http://cse.ssl.berkeley.edu/segway/.
3 See https://science.nasa.gov/learners/wavelength.
4 See http://solar-center.stanford.edu/.
5 See http://www.suntrek.org/.
6 See https://www.esa.int/Education.

TABLE 3. STRUCTURE OF BLOCK IV		
	Activity	Time allocation (hours)
1	How science works in the 21st century: SDO	2
2	Demonstrations on electromagnetism	3
3	A music star	2
4	Implementing a lesson plan	4
5	Presentations and evaluation	4

force). This global idea about electromagnetism will be explained through a set of simple demonstrations using a toy electric motor to play and listen to music and sounds. The analytical side of the explanation will be balanced by the creative way physics and music are connected. These demonstrations become an entertaining, motivating and engaging activity to teach and learn about topics in the domains of electricity and magnetism. Physics is an analytical science, but it is usually forgotten, in most educational systems, that it is also an amazing example of human creativity (Ferrari *et al.*, 2009). Physics, like literature, art or music, generates new ideas, new connections between ideas, and ways to solve problems. Raising both the analytical and creative sides when teaching physics, increases the chance students become engaged and motivated.

A toy electric motor is a cheap and easy-to-find device to teach and learn about electromagnetism. Basically, it consists of two permanent magnets and a coil of copper wire wrapped in a metal frame. When the motor is connected to a battery, an electric current passes through the coil and the metallic frame is magnetised. The frame becomes an electromagnet, that is repelled or attracted by the permanent magnets inducing the rotation of the axle of the motor. It is therefore transforming electrical energy into mechanical energy. However, toy motors could be used in a more creative way to explain electromagnetism. If we mechanically move the metallic frame, an electromotive force is induced in the coil due to its relative motion across the magnetic field of the two permanent magnets (Faraday's induction law). In the approach we took, the relative motion between the coil and the permanent magnets will be attained by vibration instead of rotation. Since music is the art of making pleasant vibrations on different instruments (metal, percussion, stringed, voice...), the toy motor will become part of different musical devices. The mechanical energy provided by the vibrations of the musical instruments will be converted into electrical energy by the toy motor.

Block IV is divided into five sessions (see Table 3): an introduction to SDO, a set of demonstrations, an activity about music, the implementation of a lesson plan by the pre-service students and the presentation and evaluation of the lesson plans. The first part of block IV introduces the students to the way science projects work, taking SDO as the reference model. Prospective teachers have no idea on how science is organized, how results are obtained and published, the availability of data and,

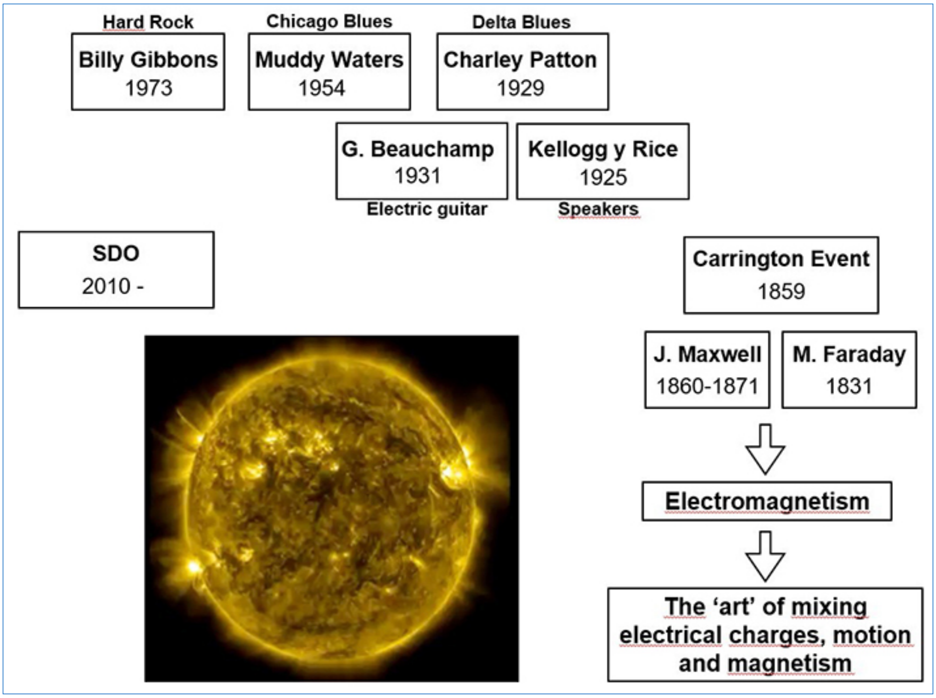

Figure 1. Elements of the story that connects music, solar activity and physics.

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more important, the wealth of educational and outreach materials readily available, including, for instance, the possibility to contact scientists to talk about their work.

The demonstrations connect the electric motor, music and SDO (solar activity) through a story that begins in 1973 with Billy Gibbons, one of the most influential guitarists of all time, and goes back in time to the 19th century, when Michael Faraday invented the electric motor (see Fig. 1). The discoveries of Faraday and Maxwell, among others, resulted in some technological applications, namely the electric guitar, by Beauchamp, or the speakers, by Kellogg and Rice. These devices had a profound impact in the music of the 20th century: music styles based on the acoustic guitar, like the Delta Blues (Charley Patton) evolved to other styles, like the Chicago Blues (Muddy Waters) or Hard Rock (Billy Gibbons). The activity continues explaining that solar activtity (from the Carrington Event to the launch of SDO) is another example of electromagnetism, on a different scale, but based in the same physics laws found in the toy motor, the electric guitars or the speakers.

This first part of the activity takes 30 minutes and it offers an interdisciplinary approach to electromagnetism through the history of music, solar physics and the history of physics. The second part of the activity consists of a set of demonstrations, where an electric motor is used to build a simple electric guitar, a speaker and a microphone (Eff-Darwich, 2021). All these demonstrations were designed and put into practise to reinforce the big idea behind electromagnetism, namely the interconnection between electric charges, motion and magnetism. The electric guitar consists of a toy electric motor attached to a one-stringed instrument. The terminals of the motor connect to an amplified speaker through an audio cable. When the string vibrates, the frame of the motor and the permanent magnets also vibrate. This motion of the magnets induces a voltage in the coil of the motor that is transformed into sound by the speaker. If the electric motor connects to the audio output of a computer or a smartphone, it will vibrate if a sound file is played. A piece of paper attached to the motor will behave as the membrane of a speaker. On the other hand, if we speak towards the piece of paper, the vibration passes to the magnets of the motor and a voltage will be induced. With the motor connected to the speaker, the voltage is converted into sound, hence we have built a simple microphone.

The final demonstration consists in dissecting an electric motor and projecting, at the same time, images of the solar activity taken by SDO, framing an analogy between the magnetic field induced in the coil of the motor with what happens in the Sun. The activity ends by highlighting the importance of SDO to understand the generation, storage and release of the solar magnetic field and its impact on the Earth. The second part of the activity takes approximately 90 minutes.

During all the activity, the teacher keeps asking questions to the students, makes them part of the demonstrations and sustains their attention connecting different ideas about music, physics and the sun. Music has been commonly used as a complementary tool in school science, *e.g.* in the form of rap practices to explain or memorize science concepts (Elmesky, 2011); however, our strategy integrates the curriculum, connecting the development and applications of the theory of electromagnetism with the birth of different music styles within a historical context. Once the activity was completed, the students (120 from the 2021-2022 academic year) answered a survey to study the impact in their perception about learning/teaching physics in primary school.

The third part of block IV reinforces the concept of interdisciplinarity; a SDO video of a solar flare[8] is presented to the prospective teachers. They have to describe which kind of emotions they develop when watching it and then, they look for a song, soundtrack or any musical composition that best matches the video and their emotions. During the fourth part of block IV, the pre- service teachers have to design a one-hour-long activity to explain to primary school students why the sun is an electromagnetic body. This lesson has to include a SDO video about solar activity. It is expected that the students connect the ideas and procedures explained in the demonstrations with the primary education curriculum. Finally, in the fifth part of the block, the pre- service teachers present their results to the rest of the class for evaluation.

Although there are many educational resources related to different fields in astronomy and adapted to any educational level, we believe the project presented in this work is the first attempt to use a state of the art scientific project, like SDO, as an innovative educational resource to teach, inspire and motivate about science to pre-service primary school teachers.

TABLE 4. FREQUENCY OF THE MOST COMMON HIGHLIGHTS OF THE PRE-SERVICE TEACHER PARTICIPATING IN THE DEMONSTRATION IN BLOCK IV	
Highlight	Number of students
Demonstrations	58
Interactivity	40
Relation to the real world	28
Explanations	27
Big idea	20
Quality and simplicity of resources	20
Applicability to primary school	13

TABLE 5. TYPE OF RESOURCE DESIGNED BY THE GROUPS OF PROSPECTIVE TEACHERS TO SHOW THAT THE SUN IS AN ELECTROMAGNETIC BODY	
Type of resource	Number of groups
Electromagnet	9
Physical game	7
Song	2
Board game	1
Dance	2
Set of experiments	4
Presentations	4

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2. RESULTS AND DISCUSSION

The results of the strategy implemented in the design of block IV (electromagnetism), based on the methodology of the Big Ideas in Science, were evaluated in terms of which aspects the pre-service teachers found more relevant (see Table 4). The use of simple and easy-to-set-up demonstrations and the resulting teacher- students interactions were the most valued aspects of the demonstrative part of the block. Most of the students did not know about the potential of such demonstrations as teaching resources. The explanations of the teacher, connected to the real world and based on the principles of the big ideas in science, were also valued positively. This is quite encouraging, since the activity gave the pre-service teachers a different vision on how to teach science, and to connect different ideas and disciplines in a practical and engaging way.

Regarding the fourth part of block IV, the students, broken in groups of 4, designed an hour long activity to demonstrate to primary school students that the sun is an electromagnetic body (see Table 5). In total, 29 different activities resulted

TABLE 6. KEY LEARNINGS FROM THE COURSE DESCRIBED IN THIS WORK	
Key learning	Number of students
Better understanding of scientific concepts	15
Confidence in teaching science	60
Variety of resources to teach science	30
Others	15

from this exercise. Thirteen groups used a more classical approach: they either built an electromagnet as an analog to the sun, or make a presentation; however, the other groups devised more innovative activities: physical games, dance, songs, board games and experiments. We found that the number and diversity of the resulting activities related to physical education is quite remarkable, and most likely due to the fact that the big idea behind electromagnetism relies on the motion of charges. The students connected the idea of motion of electric charges and the induction of a magnetic field to physical exercises, namely running or jumping. In summary, the pre-service teachers realised that it is possible to connect physics with music, astronomy or history. They also understood that rigorous explanations about physics, or any other science, could be given through demonstrations and the interaction between both teachers and students.

After completing the first semester of the 2021-2022 academic year, the pre-service teachers were asked (open question) about the most relevant aspects they learned in this course about science teaching and learning (see Table 6). These first results (more years of data are needed) confirm our expectations: the prospective teachers found not only block IV (the Sun and SDO), but the entire course as a source of inspiration for their future work in primary schools. Most of these students do not have a strong scientific background, but they have gained confidence when realising there are plenty of strategies, resources and interdisciplinary activities to teach science and to motivate and engage primary school students in science.

4. CONCLUSIONS

One of the key factors to increase the interest and motivation of primary and secondary school students towards science, and in particular physics, are the teachers. We think teachers should be trained to understand the big global ideas behind all natural phenomena and to connect these ideas in order to elaborate attracting, motivating, yet rigorous, interdisciplinary educational activities for their students. In this work, we presented an activity on electromagnetism as an example of the strategy we have implemented at the University of La Laguna to train pre-service teachers on physics education, namely: i) look for the big ideas behind the phenomena (i.e. electromagnetism), ii) make it interdisciplinary (i.e. music, history of physics and SDO images and videos), iii) explain through demonstrations, iv) ask the students about which aspects of the activity caught their attention and v) ask the students to design a simple activity about the topic to check their understanding on the big ideas and to see the originality and innovation of their proposals.

The results are positive and encouraging, especially considering that the pre-service teachers found the activity very inspiring, in the sense that they discovered new strategies to teach science. As a result, many of these students designed innovative educational resources related to SDO and magnetism that combined physics with physical education, dance, songs and even board games. Hopefully, the perceived change in the attitude of the pre-service teachers towards science will have a positive impact on the next generations of primary school students, namely interest towards science and professional developments in science.

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