The Physics and the Chemistry of Michael Faraday to form for citizenship

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Abstract. In this paper we present a teaching-learning strategy based on the life of Faraday to provide knowledge of physics (electromagnetic induction) and chemistry (chemical bonds) and a wakening to citizenship. The strategy combined a film screening with experimentation and was applied with 4 classes of the first-grade secondary school in 2014 and 2016. In all classes the discussions about the movie and the student’s reports showed that they appropriated the specifics concepts, they got enchanted by Faraday’s life and became aware of their own capacity to build their future.

1. Introduction
The official documents about the Brazilian education [1, 2] establish that the basic education must form people completely able to citizenship. In addition, they define that all curricular components must contribute to the formation of citizens. They also establish, in order to fulfill the objective of forming critical and active citizens, our education must be inspired by the principles of freedom and the ideals of human solidarity, by developing and preparing the student for life in society and for the world of employment. In this way the basic education, besides the school knowledge, also must contribute to the perception and recognition of moral, ethical and civic values, providing all the necessary tools to understand the world and the phenomena within it, both social and natural, and to understand that the application we give to knowledge is what makes them valuable to transform the world [3].

To achieve these goals, among others, there remains the urge to become aware that all boys and girls who attend public school have the right to dream of their personal achievements and/or to dream of a better future for their families. Thus, it is important to ensure that all Brazilian young complete basic education and it must provide them tools to transcend their origins. The Brazilian educational reality has been showing that this historic challenge is far from being achieved: in 2011, a UNICEF survey [4] pointed out that 1.7 million adolescents were out of school and, in 2018, the acting minister of education Maria Helena de Castro, declared in a press conference that "The high school has been the great bottleneck of Brazilian education, we started the 21st century and the problem remains, what this data is showing is extremely worrying". Therefore, considering the precarious conditions in which most middle-income / low-income young lives, it is becoming increasingly urgent that Brazilian
education provides the conditions for everyone to truly become full citizens, achieving their goals of life.

It is a fact that in an attempt to expand citizenship education throughout the national territory, several programs were created by the Brazilian government. Among them, in 2009, the ProEMI, Programa Ensino Médio Inovador, which seeks the improvement of the education’s quality through a reconstruction of the curriculum and increasing the student’s residence time at school [6]. In the participating schools of ProEMI, the student’s time at school is up to 8 hours a day and the curricular restructuring required the inclusion of some subjects such as "Literacy in Portuguese", "Literacy in Mathematics" and "Initiation to Scientific Research", among others. However, such curricular inclusion by itself does not guarantee that students develop interest in science and critical thinking about the use of scientific knowledge. Nor can the insertion of the school into this Program guarantee a better education, or that scientific knowledge contributes to the formation conscious citizens aware of their place in society.

Since the 1970s, many authors have pointed out that it is not enough to provide information across the various school disciplines and expect the student to develop the ability to correlate them alone [7,8]. In 1998, the Brazilian document which establishes the curricular guidelines for secondary education [2] included the interdisciplinarity and contextualization between the pedagogical principles guiding the organization of school and pedagogical actions. In this way, discussions on socio-political issues should not be restricted to specific school subjects. It has become necessary for all to approach or correlate social issues to their contents so that the specific knowledge is incorporated into the daily life of the student. Such an approach would contribute to a possibility of transforming its reality, in a movement of action-reflection, as proposed by Paulo Freire [9].

In this context, it is urgent to answer the question: how could physics and chemistry teaching embrace social discussions with the specific school content of these disciplines? Among the Brazilian authors who bring proposals for the teaching of physics and chemistry with such characteristics are Demetrio Delizoicov [10] and Attic Chassot [11]. The first one does that based on the problematizing education proposed by Paulo Freire [9], and the second, by dialoguing with it. The essence of problematizing education lies in the fact that the reality lived by the students is susceptible of recognition and modification by their own actions, for this reason the necessity of the practice of action-reflection together with the awareness about the historicity of their acts. In order to promote action-reflection, the teacher must know the socio-cultural reality of the students in order to problematize a situation in which the students are inserted (immersed), in order to promote their distance (emersion). This movement will help them to analyze it and to understand how they are in it and with it so that by reemerging they will be able to use the acquired (scientific) school knowledge to modify it.

In many situations, however, depending on the socioeconomic conditions of the students, even if the teacher recognizes (theoretically) that the essence of problematizing education is the teacher-student dialogic relationship that is constructed from the "problematization of men in their relations with the world " [9] and develop problematic teaching-learning strategies, he may find a barrier built by the students own hopelessness about their futures and the potential of the school education to help them build a future different from the present. In this work we report a didactic-pedagogical strategy developed by an interdisciplinary research group, which includes undergraduate students in physics and chemistry, and applied in 2014 and 2016, with students from four classes of the first secondary school series of a Public School in the city of Niterói, in addition to providing knowledge in physics and chemistry, to help in the individual and collective recognition of the historical role that every human being occupies in society, collaborating to valorize knowledge, as well as to increase students' self-esteem and contribute to form citizens.

2. Partners and motivation
The interdisciplinary team of the research group "DIECI – Desenvolvimento e Inovação em Ensino de Ciências" is composed of PhDs in biology, physics, chemistry, mathematics, and pedagogy of two public universities, one federal in Niterói - RJ and one state, in Guaratinguetá - SP. The State School where the activities were applied is located in a middle class neighborhood in Niterói - RJ, and there
are four communities in a situation of social vulnerability surrounding the school. Between 2014 and 2016 the research group DIECI, together with the teachers of the disciplines of physics, chemistry and biology of the school, developed a project in which it was responsible for all the activities / classes of the three disciplines, from integrated and interdisciplinary bimonthly planning, development of didactic-pedagogical strategies, resources and materials, to the pedagogical actions themselves. Fifteen undergraduates of the teaching courses of biological sciences, physics and chemistry (5 of each course) were participating on the project. Between 2015 and 2018, some of the strategies developed were also applied in the classes of Initiation to Scientific Research, a member of ProEMI, with classes from the three secondary school series.

During 2013, the interdisciplinary team carried out a detailed survey of the physical structure and the pedagogical, technical and human infrastructure of the school. It was also observed the classes of 9th grade elementary school and the 1st grade of secondary school, both during science classes and other curricular subjects. In this period of observation there was no interpersonal interaction between observers and students. The college joined ProEMI in 2014, becoming a full-time school and including in its curricular adjustment the discipline of Initiation to Scientific Research. The school had good and well-maintained physical facilities, but it did not have a science laboratory with appropriate space and infrastructure to classes with students of basic education. Most computers in the computer lab did not work and there was no internet connection. The analysis of the notes made during the observations indicated that in general students presented difficulties in mathematics, reading and interpretation of texts, as well as expressing ideas in writing, difficulty in concentration and abstraction, immediacy and lack of interest in studies. The school's biology, chemistry, and physics teachers agreed with the team's findings. [DIECI files]

The four classes referred to in this paper were composed mainly of young afro-descendants with an average age of 16 years who lived in the four communities, living and experiencing daily armed conflicts between local gangs. Added to these occurrences, they suffered from the tensions involved in police operations and the violence associated with drug trafficking. Consequently, by living in such a place, students also suffer from a series of oppressions, prejudices and discrimination throughout their lives that discourage them and decreases their self-esteem, which causes hopelessness and reduces expectations of future possibilities.

In the pilot class (2014) the interdisciplinary team interacted with students four times a week during biology, physics, Initiation to Scientific Research and chemistry classes (100 minutes each). At the end of the second trimester, we concluded that despite the pedagogical work and the evolution observed in the students' commitment and performance, they still believed that their future was predetermined by their economic condition and their belonging to the communities wich they were born. At that time, they did not consider that education could provide them tools to make them agents of transformation in their reality or transcendence of their socioeconomic origin. They did not believe that they could go to university. The only student reporting the dream of going to university was born. At that time, they did not consider that education could provide them tools to make them agents of transformation in their reality or transcendence of their socioeconomic origin. They did not believe that they could go to university. The only student reporting the dream of going to university was born.
3. Development of the strategy

According to the Minimum Curriculum of Rio de Janeiro [13], the subjects to be worked in the third bimester of the first grade are: biology - Theories of Evolution, chemistry - Chemical Bonding and physics - Special Relativity, and the electricity, magnetism and electromagnetic waves are subjects of the third grade curriculum. According to the work methodology of the interdisciplinary team, weekly meetings were done to search for themes / problems of work without succeeding on identifying one related to the reality of the students, whose understanding demands knowledge about the subjects treated in the three disciplines.

Considering that the historical period in which this knowledge began to be developed or reached a better understanding began in the 1830s, it was decided to organize the Integrated Bimonthly Planning (IBP) from the historical-social contextualization of the knowledge and use the questions related to the reality of the students to problematize specific subjects in each discipline. Michael Faraday, is one of the greatest highlights of that period and is directly linked to the contents of chemistry and indirectly to the physics of the bimester. Since his life path provides several opportunities to promote reflections on poverty, intelligence, character and values, it was decided to use it to support the didactic-pedagogical strategy demanded and to apply the activities that composed it in the first classes of the third bimester.

The preparation of the team for the construction of the IBP took place in weekly systematic meetings with the undergraduates to review the specific contents of the disciplines, studies about the industrial revolutions and the social, economic and environmental changes that came with them, the biographies of Darwin, Faraday, Humphry Davy, Maxwell and Einstein, among others. In particular, studies and discussions on citizenship and the development of citizenship have been carried out, especially based in Adela Cortina [3] and Boaventura Sousa Santos [14]. The IBP is always organized by week and contains the description of that the DIECI team calls “class progressing”, a detailed description showing how to work with the students in each lesson / activity in each discipline throughout the week. As the strategies, multimedia materials, audiovisual materials, experiment kits, supporting texts etc., that will be used with the students are made and the pedagogical situations training are happening, the IBP changes and receive some adjustments. The same occurs as the classes / activities themselves are performed.

To present Faraday's life path, the team watched a variety of audiovisual materials and selected the episode 10 of the TV show “Cosmos: a Spacetime Odyssey - The Electricity Boy” [15], presented by Neil deGrasse Tyson, which deals with life and work of Michael Faraday on electricity and magnetism, culminating in the Law of Electromagnetic Induction and the electromagnetic character of light. This choice determined the organization of the strategy in two activities.

In the first one, the episode would be shown to the students in full length but with four experimental pedagogical pauses. During them the students were divided in groups of up to six members, to carry out experiments similar to those presented in the film. For that, the activity got the name "Cinematory". For that purpose, experimental kits with low cost materials were produced for the Oersted Experiment, Electromagnetic Induction, Magnetic Field Lines and Electric Motor, with five kits from each experiment. The Electric Motor wasn’t similar to the one shown in the video because Faraday used mercury.

In addition, others pedagogical pauses were programmed to discuss Faraday’s socioeconomic status and the socio-scientific culture at the time. The display times for such pedagogical pauses to occur were determined during an episode viewing for the entire team, from the requests made by the undergraduates, both to ask questions about physics, London society and to make suggestions. It was established that during the activity students could also request the interruption of the video whenever they needed explanations or the wish of express their opinions.

The second activity was based on the lesson III (Cohesion – Chemical Affinity) of Faraday's book “On the Various Forces of Nature and Their Relations to Each Other” [16] and planned to be developed with students through investigative experimentation on ionic conductivity and electrolysis. Once again, the students were organized into groups of no more than six components. They would receive the kits and performed, without the use of written scripts or verbal instructions, the experiments of ionic conduction and of electrolysis of water. In the end, they would write reports with their observations, discussions, and
conclusions. Then they would socialize their conclusions with the class. It was intended that the socialization and comparison of the results of the two experiments would provide the discussion on the types of chemical bonds. The experimental kits for the second activity, six for each experiment, were also made with low cost material. “Figure 1” shows a sample of each experimental kit made and used in both activities.

![Experimental kits](image)

**Figure 1.** Experimental kits produced: (a) Ionic conductivity, (b) Magnetic field lines, (c) Electric current induction, (d) Electric Motor, (e) Oersted’s experiment and (f) Electrolysis.

It was also decided that in the two activities, during the experiments, each group would be accompanied by an undergraduate that would guide the investigative experimentation, encouraging the participation of all the students of the group in the accomplishment of the experiments, instigating the curiosity and to debate their conclusions. The preparation of the undergraduates was carried out through pedagogical situations training of the two activities, at which time they acted as students of basic education, or as guides of experimentation. On two occasions the professors of DIECI acted as students of basic education.

Finally the group established that both activities would be evaluated by the qualitative methodology, with participant observation [17, 18]. In this way, the teachers and each undergraduate would act as complete participants, producing individual records analyze of the activities. All of these records would contribute to the evaluation of both the experimental kits and the experimental methodology as well as the use of the video and the class progressing for each activity. In the first activity the observers were instructed to record in their field notebooks: (I.a) if the proposed class progressing of activity was sufficient to achieve the objectives; (I.b) if the audiovisual material awakens awareness for the general theme. In addition, for each situation addressed: (I.c1) if the students’ perception and learning were actually achieved, (I.c2) if they participated by requesting more pauses and (I.c3) bringing discussions beyond those planned by the team. And, for the second activity: (II.a) if the proposed class progressing of activity was sufficient to achieve the objectives; (II.b) if whether the questions proposed in each case were adequate and sufficient to guide the experimentation; (II.c) if all students engaged in the experiments; (II.d) if alternative procedures were
proposed for the realization; (II.e) if whether or not they were able to reach conclusions; and, (II.f) if whether the students' perception and learning were actually achieved.

4. First application
On the first day of classes of the third bimester in a Monday at 07a.m., time of the physics class, all the students of the pilot class attended the school and participated in the activity Cinematory. This fact was reported by the teachers as unusual, because in the other classes as it used to happen in the first week of classes after the holidays the absence of students was great. The activities took place in an ordinary classroom, attached to the tiny science lab, which had a marble table in front of the board, a computer, an image projector, and a set of wooden wallets. The pilot class was composed of twenty students who were organized into five groups and oriented that they could request the interruption of the exhibition of the film whenever they wished. Due to the reading difficulty presented by the students a dubbed version of the episode was used.

The students recognized Neil deGrass Tyson because we had used an excerpt from an interview of him in an activity in the previous bimester. Likewise, they quickly identified the house of Isaac Newton. They did not associate “little Albert” as Einstein. They demanded a pause to ask if it was true that in London the teacher could beat the student. We have discussed the issue of punishment of children in the past, both in the family and in the school environment. We clarify that they occurred in all countries, and that they became illegal recently, especially after 1990 with the “Estatuto da Criança e do Adolescente”, in Brazil. Shortly afterwards, it was necessary to explain the system of apprenticeship training in the 1830s in England, and that the lighting of houses and buildings was made by gas lanterns. They called Humphry Davy of fool, by the accident represented in the episode. We then recall some of his scientific contributions, shown in Chemistry classes in the second bimester period and discussed how the evolution of knowledge provided the adoption of safety standards for laboratory work.

The students doubted the veracity of the Oersted’s experiment shown in the video and were surprised to see it. They wanted to know why. Although they were encouraged they were unable to formulate hypotheses, we explained that we needed their ideas to discuss, we did not provide explanations and we suggested that we continue to watch the episode. Then the film showed the experiment of the electric motor and the students were amazed by the geniality of Faraday. But as the scene did not show a complete view of the equipment as the needle rotated, we paused the film exactly in the image of the equipment and start to indicate on it what should be happening as they suggested the direction of the electric current and the course. But it was only when they replicated the experiment, using a material with a very different design, that they understood their layout and began speculating on the interactions that might be taking place.

One group asked if they could test the compass with the magnet repeating what they saw little Albert Einstein doing at the beginning of the video. All of them replicated the experiment, and in each group we observed them arguing until they formulated that “if the magnet moves the needle of the compass and the electric current does the same, then the electric current behaves like a magnet”. In this moment, the undergraduates asked how the phenomenon occurs, since neither the magnet nor the wire touched the compass. Most remembered the Law of Gravitation, saying it was like the sun and the planets, a “thing” at a distance was happening. We speculated that without the mention of Newton in the video, they might not make that connection.

Following the video they were impressed by all the influence that experiment had brought to our way of life. However, they expressed great indignation about Faraday's reaction to Davy, when he was involved in the project to discover the Bavarian recipe of glass, preventing him from continuing his work with electricity. They asked why he had not refused, why Davy did that. We detail the relationship between Davy and Faraday, including the chronology of events, we explained how the task was imposed, the social structure of the time and the prejudices that Faraday faced in the scientific community due to its origins and lack of schooling. The students expressed their indignation with phrases like “I’m glad I did not live then”, “it must have been very bad to live in those days”. They asked if Faraday had ever outraged against Davy. We said no. That there are even correspondence records where, in response to a negative comment about Davy, he expresses his
gratitude for the opportunities that Davy provided him. Several students stated that they understood that Faraday was a very good person, religious and had good character, but that in his place they would speak badly of Davy.

In the electric current induction experiment we used a multimeter to check the induced current. Voluntarily, the students tested the current generated by the battery on their chair before stating that the voltmeter was indicating current flow in the coil. When we asked to relate their observations to earlier experiments, they were quick to say “electric can influence the magnetic and magnetic also influences electric” and that “just as the currentless wire does not act as a magnet, the stucked magnet does not do the current to appear”. Afterwards, when the film quotes Faraday’s illness, which in the animation he expressed to his wife the fear of losing memory, the students became very anxious and started running over to ask if he had healed, and they were relieved as it quickly became clear that he kept his scientific activities and developed the concept of magnetic field.

The students requested a pause and asked if it was the magnetic field of the magnet that generated the current. We fixed the film in an image that showed the drawing of the field lines and asked what would happen to them when the magnet moved. They replied: “They will move with him, they are from his magnetic field”. We asked if the magnetic field would have the same intensity everywhere in the space around the magnet: some groups discussed the shape of the field lines, others moved the compass around the magnet, but in the end everyone concluded that the intensity of magnetic field varies. This discussion progressed until they concluded that the variation of the magnetic field was responsible for the induction of electric current. Then we introduce the concepts of electric field, induced electric current and induced magnetic field.

After that, the episode shows Faraday’s innumerable attempts to verify if the light interacts with the electromagnetic field. Although they had not understood why Faraday had succeeded in using one of the pieces of glass he had made on Davy’s orders, they celebrated the success. This experiment was not reproduced. We discussed the experiment using figures traditionally used to explain the polarization of light and the propagation of plane-polarized light until we realized that they had understood it. One of the students wrote that “electric field and magnetic field are related. Light is electromagnetic wave”.

We paused the video when Faraday began an experiment to check the magnetic field lines around a conductor wire using iron filings. The students replicated the experiment that Faraday draws the field lines of a rectangular magnet, using a tray lined with a sheet of A4 paper. They could move the magnet to check if the format of the field lines changed. In addition to encouraging them to do so, we provided magnets with other geometric shapes so they could check if the shape of the field lines changed. At the end we asked them what they thought that would be the field lines in the film’s experiment. Everyone agreed that it would be circular.

Afterwards, the students got enchanted by the video because the explanation of the Earth’s magnetic field. They came back very touched when Tyson describes that by the barrier imposed by mathematics, Faraday did not model those phenomena, which he explained so well and because of that he suffered more discrimination. Stating that this was the only area in which his poverty had limited him, emphasizing that it was due his lack of formal education. But soon they got impressed when the episode claims that Maxwell sent a copy of his “On Faraday's Lines of Force”, paralleling the text Faraday sent to Davy in the past. They wanted to know even if they were friends. We explained Maxwell’s admiration for Faraday and committed ourselves to distributing to the class copies of the Faraday text written for Maxwell and reproduced in “The Scientific Papers of J. C. Maxwell, v. II, p. 786-793, Cambridge University Press, 1899”. We selected some pictures in the “Figure 2” to show the moments of pauses to students perform the experiments.
Figure 2. From left to right: students of the pilot class performing the experiments of Oersted, electric current induction and magnetic field lines.

The second activity occurred on Thursday in the Chemistry class, in the same space and time, also with the 20 students present and in which the compositions of the groups were kept. We told them that they were about to do experiments also performed by Faraday. The groups received the kit for the ion conductivity experiment (device with one lamp, switch and conductive wire with plug, a beaker with water, one with salt and one empty). They noted in their notebooks the list of materials and went on to describe the characteristics of the substances. When they finished we informed them that the liquid was water and the solid was cooking salt. They asked about the cooking salt formula and it was written on the board. For all groups the initial question was how would they turn on the device lamp. They replied that it was enough to plug the plug into the socket and turn on the switch. The frustration was general when the lamp did not light up. They complained that the lamp was burned. They were then instigated to analyze the current flow and concluded that the circuit was open. They used a small piece of rigid lead wire with bare tips to close the circuit and found the lamp was working. We removed the piece of wire from the table and asked how they would light up the lamp. We informed them that they could do the tests they proposed as long as it was based on a hypothesis, that they could not make use of the material without first explaining what they intended to do and why they decided on that procedure.

The development of the experiments had a huge variety between the groups. Some of them focused on the discussions or better elaboration of their hypotheses and answers when questioned. Everyone concluded that water and solid salt did not conduct electricity. The next step was much slower. Only one group was reminded without our encouragement of the discussions on ions and ionization energy, asking how they could “separate the sodium and chloride atoms and ionize them” and explaining that they wanted to do so “because the ions having charge would move between the poles of the device, because these also had charge that would attract the ions”. We recall the discussion about stability of the chemical elements and they remembered that sodium was one of the elements whose stable form in nature is not the neutral element, which was found in sea water and concluded that in the salt water the sodium chloride was ionized. Despite the difficulties presented, no group gave up, thinking and looking for possibilities to continue the experiment. We decided to let them work only on this experiment during that class. All ended up achieving the expected conclusion. They also performed various tests with other substances, such as water from school drinking fountains, water with sugar, water with lemon juice and soft drinks, and concluded that the atoms that formed water and sugar were not ionized as salt.

The activity was finalized in the Initiation to Scientific Research class on the same day after lunch. The students did the water electrolysis experiment. They were allowed to start the experiment without making assumptions, but could only finalize it when explaining what they were observing. Again the group that had thought about ionization in the morning was the first to reach the appropriate conclusions: that at the poles the Hydrogen and Oxygen were separated from the water molecule, that this separation was spending energy, that in the tube where it formed the greatest amount of gas was
hydrogen, “because the water formula is H₂O, so it has twice as much hydrogen”, and they suggested “blowing up” the Hydrogen to test if they were correct. They also concluded that the stable state of Hydrogen and Oxygen in nature was gaseous instead ionic like were Sodium and Chlorine. By the end of 50 minutes everyone had finished the experiments. During the socialization of the results the students who had presented greater difficulty, listening to the explanations of the colleagues, reworked their hypotheses and conclusions. They themselves suggested that the name of the chemical bond in NaCl should be ionic and had no difficulty understanding the electron sharing in the covalent bond. “Figure 3” shows moments of the chemistry experiments.

Figure 3. On the left a view of the class during the experiment of ionic conductivity and on the right they were verifying the presence of hydrogen obtained on the electrolysis of water.

To finish the discussion we recall the contributions of Faraday presented in the Cinematory activity and show some of the modern applications of electrolysis. And we watched the students discuss which of Faraday’s works was brilliant. We remembered Faraday’s self-learning and show slides with some photographs of the Faraday Memorial. That’s when one of the students said “and he was poor, right?” He had spoken quietly and when we said yes, colleagues in the other groups asked what we were talking about. We were quiet. He drummed his fingers on the table, looked at his colleagues for a short time and repeated aloud “He was poor, guys!”.

Here we saw the first step towards the rescue of dreams. The student did not complete the sentence, but it was not necessary. The way he spoke and looked at his colleagues made it clear: they could reach new horizons as well! The students clearly realized that they themselves had come to the conclusions, that they too were capable. For the rest of the class, they crowded around our copy of “The Chemical History of a Candle; The Forces of Matter” reading sentences, looking at the figures. When we said that Faraday himself had drawn them, they shouted the name of one of the students in the class who also drew very well

Several students asked to borrow the book, which was passed from one to another over the two months.

The impact caused on the students by Faraday’s life path and work was very intense. Michael Faraday has become almost a motto. In different situations the students of the pilot class showed that they remembered his history and works. After these activities, the students moved closer to the team, including asking us to set extra hours to help them with the exercises. As there was no vacant time in his school grid, this attendance happened three times a week, one for each discipline, during lunch break. Three months later, when they had the opportunity to perform a demonstration of experiments for students and professors at the Institute of Chemistry of the Universidade Federal Fluminense, they accepted without fear and there was a dispute to know who would present Faraday’s experiments. During the show they surprised us because so many things that talked about Faraday had not been presented in the movie or in our comments, showing that they had voluntarily searched to know more

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1The student quoted had been identified with gifted behavior towards the arts through another project developed by one of the authors in public schools to her project for the doctorate.
about him. It was also evident how proud they were of speaking to people at the university. After that, there was a change in the attitude of the students who started to plan for the future, including attending a university. At the end of 2014, one of the students changed to a technical school, in the farewell he declared that he would pursue his dream of studying gastronomy. Currently 9 students of the pilot class are in university in courses of several areas.

5. Other applications
The students of the three classes of the first grade of the High School, class A - 22 students, class B - 13 and class C - 15 students, where the applications of the strategy occurred in 2016, although they were from the same school, did not have previous contact with team of DIECI. In each class the strategy was applied in the first classes of the 3rd bimester, in the classes of the discipline of Initiation to Scientific Research, respecting in each week the sequence: class A, class B and class C. The students were organized in groups, as planned, of no more than 5 students, and received the same initial instructions as the pilot class.

According to the teacher of the discipline the students were used only to expositive classes of chemistry and physics. This would be his first contact with problematizing and investigative pedagogical activities. Thus, the team reviewed the class progressing of the strategy making small adjustments to expand the possibilities of dialogue with the students. In this process, we set aside for the presentation of the team, increased the number of pedagogical pauses, particularly in the early part of the film, and programmed questions that encouraged student participation in the conversation, helping them to become used to the proposed dynamic. This alteration helped to show that several electrical phenomena were already known at the time, although that Michael Faraday had participated in the early knowledge of electricity. It also contributed to a broader discussion of issues within the sociopolitical context of London society, and promoted a deeper reflection on both scientific and social stratification and the prejudices addressed in the episode.

In all classes the students got deeply sympathized with the financial situation in the Faraday’s childhood. When the film shows their family with few resources even to eat, it was possible to listen to comments like “Poor boy!” and “Oh, what a pity for them!” In the same way, many students revolted with the authoritarianism imposed by the teacher and the subsequent departure of the scientist from the school. At this point, a student in class B asked, “How did he become a scientist after he left the school?” The team took this pause to highlight the importance of education in people’s lifes and showed that Faraday’s interest in the knowledge of the natural sciences was so great that he devoted himself to learning them.

An extremely remarkable moment occurred in the classe C. Soon in the first video class a student was surprised by the fact that Neil DeGrasse Tyson was black as the student, and was talking about science. The way the student expressed himself and the intonation used was a completely new situation for him. This led the group to an important discussion about the possibility of black and poor people participating in scientific and technological development. We’ve talked about Tyson’s trajectory and that he is also one of the leaders in a series of interviews for reasons of racism and reasoning without scientific and academic background, emphasizing that today he is a defender of the effective and complete inclusion of minorities in the academic world.

In both activities it was evident the enchantment of the students for they are realizing experiments. It was possible to discuss the concepts associated with the experiments, but the students presented more difficulties with the handling of the materials and we realized that some of the initials bimesters contents were totally unknown by the students of the three classes. Oersted’s experiment, though very simple, caused most of it a “magical” effect, for “the compass moves by itself”. We suggested they to move the compass and they perceived the dependence of the effect caused with the distance. In the experiment with the coil, many students were fearful of the possibility of a electrical discharge, but were delighted with the “simple way to generate current electric power”. And they showed great admiration when comparing the experiment of the electric motor to the various technological devices that coexist in their lives today. But the true ecstasy was due to the experiment of the magnetic field lines with the iron filings. All groups moved the magnets and described the changes observed in the
distribution of iron filings, making it possible to discuss the concept of the field and its spatial compliance in three dimensions.

In the second activity, the difficulties with experimentation and concepts were even greater, requiring in some cases to explain some contents and concepts, including the difference between ion and neutral element. But, in the end, the ion conduction and electrolysis experiments enabled the conclusion that to form substances the atoms bind in two different ways, as well as in different proportions, and everyone was able to understand the differences between ionic and covalent bonding. “Figure 4” shows moments of experimentation in the Initiation to Scientific Research classes. Once more the modern applications of electrolysis caused astonishment and further evidence of Faraday’s geniality. In the three classes, the admiration and respect shown by Faraday were identical to those observed in the pilot class.

Figure 4. Above, from left to right, students performing the Oersted experiments, current induction and magnetic field lines. Below, the experiment of ionic conduction, to the left, and electrolysis of water, to the right.

The experimental activities that make up this strategy made it possible to conclude the importance of Faraday’s work on the way of life of contemporary society, leading them to conclude about the geniality of the scientist. Furthermore, the undergraduates’ approach to the students facilitated the teaching-learning process, due to the dynamics that involved a dialogic relationship associated to the investigative approach of the experiments. This fact can be verified through the evaluation of the activity done by the students themselves, in which they reported enthusiasm when carrying out the experiments and demonstrated the importance of such activity for their teaching. The aspects related to the life of Faraday sensitized the students as they compared them with their own realities, provoking empathy and identification with the limitations and financial conditions of the same. It was verified in all classes the admiration for the man who, despite humble origin, became one of the greatest scientists of his time.
6. Final considerations
The evaluation of the activities, materials and class progressing proposed for the strategy showed that: i) the previous qualification of the team was fundamental for the success of the activity, ii) the breaks and the way in which the social discussions were accomplished fulfilled the intended purpose, iii) the experimental kits, although very simple, allowed the students to carry out the experiments in an investigative way, proposing hypotheses, reflecting on procedures to test them and being aware that they arrived at the conclusions, iv) the investigative experimentation contributed to the students to improve the capacity to express themselves (v) the questions and provocations planned to guide the experimentation were sufficient to assist the students without providing procedures, (vi) the pedagogical situation training enabled the undergraduates to act as guides in the activities; (vii) the students were conscientized that, regardless of social issues and its consequences, being poor just means having no financial resources and not having access to the goods that money can acquire. In general, strategy planning / class progressing contributed to the development of human skills as abstraction, collaboration, argumentation, decision making, socialization, autonomy and leadership, communication, reading, writing and synthesis of ideas, as well as developing citizenship.

For the undergraduates, the whole course was an odd opportunity to think, plan and execute interdisciplinary teaching and learning of sciences from social contexts aimed at training for life in society. All the undergraduates expressed their satisfaction to be able to participate in the development of these students, as well as to extend the bond with those classes, surpassing the formal and traditional relationship of teacher-student or tutor-student to an emotional bond that allows the development of empathy as a fundamental skill in the dialogic relationship of the educational process. We selected three statements:

“In this process I experienced the importance of “learning how to do”, because the students’ curiosity about the experiments and advances achieved was perceptible. The reflection provided was extremely important for my training because I realized that it was the first time which I truly believed that those students had an interest in LEARNING, and that this competence needs to be instilled responsibly and pleasantly, that the way a resource is used might or might not lead to the construction of knowledge and the importance of a planned lesson in order to develop social skills from content and not just to develop content.”

“As interaction and dialogue was intensified, the trust between us increased and many asked for guidance not only on the specific content of our discipline. When I was able to experience this, I understood for the first time the real importance of a teacher expand his general knowledge. Because it will help the students’ personal development and also in acquiring specific knowledge. Moreover: I understood the dimension that an interdisciplinary work achieves in the life of the student and teachers.”

“Making the things all the same is comfortable, but the opportunity to reinvent itself requires getting out of the comfort zone. To build a pedagogical practice that goes beyond pure physics, require lots of study and planning. The Cinematory activity brought me the opportunity to reinvent myself, rethink, dialogue, grow up and got the sensitivity to look at each student as unique. In addition, working in an interdisciplinary activity, which requires a dialogic relationship with different areas, and above all planning to achieve success, is a great opportunity in the formation of a teacher who intends to be committed to the transformation of the reality of his students. I understood in this activity the importance not only of socializing knowledge of physics, but provoking a change in the posture of students facing their possibilities of future transformation.”

For the group of students of basic education it was possible to verify that this strategy effectively led them to start the academic career. For the undergraduates and teachers of the team, the whole course has allowed us to deepen values such as courage, creativity and respect so that the students became able to defend their ideas, have acquired a commitment to their own life and legal behavior
under the laws that govern their country. In order to they truly exercise their citizenship respecting the dignity of every human person and preserving the planet. The rescue of citizenship and its exercise corroborate the effectiveness of this type of strategy, especially as regards the association of scientific contents related to physical and chemical sciences with social and economic aspects, related to the reality of the scientist and its evolution as a citizen (or social being). Just as is the practice of our team, we emphasize that this experience was only possible thanks to the detachment of the classical scientific and educational paradigm, from daring to try the new and the interdisciplinary work supported by intersubjectivity.

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