What and How to Teach Didactics of Physics?An Approach from Disciplinary,Sociocultural,and Interactiona Dimensions

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Abstract. The question about what to teach in a physics course apparently has concrete answers depending on phenomena that you want to study such as optics, mechanics, electromagnetism, etc. However, ask about what to teach in a didactics of physics course? It does not seem to have concrete or unified answers. This study aims to propose a structure to work didactics of physics in a teacher education program from three dimensions, based on research results. We developed a phenomenological research design in a qualitative perspective with 14 pre-service physics teachers. We characterized the Didactics of Physics trough disciplinary, sociocultural and interactional dimensions, and consequently, we design and apply a teaching methodology, to analyze the impact and validate this dimensional proposal. Data analysis let us say that take this dimensional perspective to structure objectives, contents, and strategies to decide what and how to teach didactics of physics is highly relevant. We present evidence that pre-service teachers recognized that preparing a physics class requires them to review their capacity of (re)cognition of physics knowledge, their criteria to relate different disciplines to solving physics teaching problems and, understand more broadly different ways to enrich interaction in the classroom. In front of which this proposal contributed importantly to overcome the technical and instrumental vision with is usually assumed teaching didactics.

Keywords: Physics teacher education; initial training teachers; dimensions of didactics of physics.

Introduction

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How to educate in didactics of science? is a current global problem, because the academic community has become aware that is so difficult to train teachers to produce own criteria that allow them to determine new objectives, contents, and methodologies to teach science, in this case, physics.

In this report, we are defending the idea that one way to help to solve this problem is to expand the meaning of teaching Didactics of Physics. We think Didactics of Physics is more than technical or instrumental skills to manage support resources in the classroom or introduce technologies. This field can be developed from a multidimensional perspective that involves specific contents, to educate future teachers to take coherent decisions to the class in a particular context, to be autonomous in the understanding of what, how, why and to whom he will teach. For that, we combined knowledge offered by disciplines of Exact Sciences interrelated with Human and Social Sciences.

Theoretical framework

With the aim of tracking how researchers in the area understand didactics of Physics, we analyze information on three aspects viewpoints about the problem of improving training teacher's programs and its relationship with didactics of physics, perspectives about what it means to teach science, and views about specific didactics.

Concerning the problem of improving training teacher's programs, we found that in recent decades there have been studies highlighting the need to transform curriculum and ideologies that underpin its development. For example, (Carvalho & Gil-Pérez, 1993) invite us to look beyond the common sense about teaching, regarding what does mean to teach and learn science, to guide teaching practice as a collective work of innovation, and to relate research and educational practices exceeding the mere transmission of knowledge. In this sense, García-Carmona (2009) highlights the necessary relationship that should exist between research and teaching when speaking of didactics of physics. Teachers are currently called to overcome the class based on the transmission of information. They are challenged to be able to have autonomy to solve real learning problems in complex environments, from reflections on their teaching practice, developing proper communication processes with their students, teaching in a contextualized manner, and meeting current demands of society.

(Marcelo, 1999), also notes that to achieve real transformations it is necessary, to begin with, overcome some paradoxes of teacher training, such as presenting the subject in a complete, objective, absolute, and accurate way, but simultaneously requesting that the future teacher teaches from a problem-solving and alternative perspective. Or, working in class mainly with expository methods but demanding that prospective teachers use diverse strategies meeting the needs of diversity through an interdisciplinary approach. Or, using an authoritarian approach to classroom discipline but asking future teachers to develop autonomy in their students. These are paradoxes whose solutions are real challenges for research in teacher training.

We can say that literature has shown a set of possibilities that could guide the necessary transformations, such as proposals for the development of the critical, discerning, investigative, autonomous, and intellectual professor, all incorporated in streams of thought from various viewpoints, which require the seeking of higher consensus or rendezvous points.

In this regard, we believe that teaching Didactics of Physics should guide pre-service teachers in deepening his domain of physics but should also build specific knowledge of how to teach and how to understand those to whom he will show a particular content in different context. Therefore, this research revolves around the search for greater clarity on the meaning of the objectives, content, and teaching methodologies of Didactics of Physics.

Respect to what its mean to science teaching area, we can say that in the international context, the Science Education, has consolidated as a research field; however, with a high diversity of perspectives, and still quite distant from the daily practices of teaching in schools. For example, in the Brazilian context (Author, 2005) showed that this field of knowledge comes from the existence of a history of sharing some common concerns, but not their organization about a hegemonic paradigm. Some European and American trends, from works such as (Astolfi & Develay, 2002); (Carvalho A., 2004); (Cachapuz, Praia, & Jorge, 2002); (Fensham, 2004); (Sanmartí, 2002); (Viennot, 2004) show a consensus about training science teachers require reshaping, founded on research results, and more significant interaction between teaching and research. However, simultaneously, they show differences in topics such as the definition of what are the fundamental subjects of study in this area. For example, whether it focuses on the study of teaching methods, or the necessary knowledge of the teacher, or ways to deal with the student assumptions, or on the objectives of teaching the sciences, or on which contents to teach or why teach to teach them in a given context.

Finally, respect to the viewpoints about specific didactics, we found there is some consensus about the particular development of teaching contents for each scientific discipline. (Sanmartí, 2002) considers, for example, that the knowledge of Didactics besides being the synthesis of various disciplines, is formulated based on the problems and the conceptual structure of each scientific discipline, posing specificity in the teaching practice and requiring the construction of knowledge for the specific teaching areas.

Meanwhile, (Astolfi & Develay, 2002) concluded that Didactics studies particular classroom topics, such as the student representation of students and teacher intervention. But these issues should be explored concerning the disciplinary knowledge; in this case, Physics. They also warn of the necessity of not falling into thinking regarding a "General Didactic Approach" that does not adapt to actual teaching processes, or to a "Specific Didactic Approach" that is only focused on the teaching of the science itself, forgetting educational goals.

Consequentially, we agree with the idea of "Didactics of Physics" is an interdisciplinary field. It takes knowledge from Epistemology to help in understanding conceptual constructions, for example in the (Hashweh,1996) perspective to know teacher's beliefs about how to detect student conceptions and work on it, as well as to plan and improve teaching strategies. Pedagogy, to study trends of teaching models and their respective analyses, for example in the Klette, K. (2007) perspective to overcome the distance that persists between the theories about novelties process of teaching and learning and the scientific contents. Cognitive Psychology to study learning processes, for example in the Lupu, C. (2013) view about designing exercises for teaching based on the psychological and epistemological structure of the scientific discipline, as well as alternative methods of evaluation. History and Philosophy of Science to analyze paradigms and reasons for scientific facts. For example, as showed by Sales, Greca and Freire (2012) about foster a more mature vision in students in respect of their understanding of the Nature of Science, as well as, improve the quality of argumentation and metacognition in teachers and students, among others disciplines.

So, we work around the question about the criteria by which to organize objectives, contents, and methods for teaching Didactics of Physics. We unfold this problem with three questions; How can we harness the various disciplines when teaching Physics Education? What kind of activities is most appropriate to achieve an interdisciplinary focus in Physics Education? How can we go from simple to complex, or from primary levels to higher levels in learning the Didactics of Physics?

Methods

The participant

We designed and offered a course to a group of pre-service physics teachers from a university in the state of São Paulo, Brazil. This course was developed in 60 hours with 14 students, during 15 classes, applying and analyzing processes for teaching and learning Didactics of Physics. The plan for each group contained elements such as objective, thematic content; interaction methodology; evaluation strategies; supporting material for classes (produced specifically for this purpose); and theoretical framework for different topics.

Data collection

This research is characterized as qualitative since the problem to solve arose from reflections about how to teach didactics of physics. We formulated a proposal for the objectives, contents, and methodology that theoretically should be considered when working in teaching Didactics of Physics. After that, we characterized three dimensions that allowed us to organize this knowledge in a structured and interrelated manner.

Data were taken from the development of activities through observation and intervention, for which we construct texts to be analyzed. We were investigating data collected simultaneously with the development of the course since it was being reformulated based on the partial results obtained. Now we will present an overview of the course structure and the definition of the dimensions based on which we organize the sequence to take data.

1. Defining objectives, content, and methodology for teaching Didactics of Physics.

After analyzing theoretical framework, seeking a correlation between the different perspectives, and making a summary, we conclude that some objectives to teach Didactics of Physics are:

- To contribute to teachers' comprehension of methods of interrelating knowledge from different academic disciplines for problem-solving unique to the Didactics of Physics;

- To contribute to the improvement of future teachers' "common sense" view of the teaching and learning processes;

- To foster critical thinking skills in teachers in the reality of their environment as well as in their mastery of content and their professional activities;

- To contribute to teacher training both in research in teaching physics and in using research results in this area; and,

- To contribute to teachers' professional growth upon their mastery of specific concepts in the field of teaching physics.

Upon formulating these objectives, the question arises about the type of content that can and should be taught to achieve them. It is necessary, therefore, to create a theoretical corpus for the Didactics of Physics coherent with the proposed objectives, realizing that such content should be classified in a field between natural, human, and social sciences.

Therefore, we consider that teaching Didactics of Physics is not the teaching of any of these areas alone, but rather content from various disciplines arranged and combined to solve physics learning problems. Then, we propose groups of subject matter, characterized by the role they fulfill in the process of equipping the future teacher to address the subject of physics under different determinants. These dimensions are disciplinary, sociocultural and interactional.

Disciplinary, Sociocultural and, Interactional Dimensions.

(a) Disciplinary Dimension: Is about the (re)cognition of the disciplinary knowledge of Physics. We consider that the quality of instruction from the physics teacher, and his autonomy increases in the same proportion that increases his capacity of (re)cognition of physics knowledge. Therefore, this dimension requires methodologies based on metacognitive exercises. To this end, the subject matters of history, philosophy, and physics epistemology can be appropriate, since they allow the treatment of physics from fresh perspectives, permitting the identification of explanatory outlines and problems formulation related to the comprehension of physics concepts.

There are problems which generate questions about beliefs that undergraduates have on topics such as "the problems of physics," "the explanatory models," "the nature of concepts," and "the observables," among other aspects which pre-service teachers assumed to be understood but which are highly sophisticated.

Also, in this dimension, we can teach reflection about individual effort and reflection for action, discussing their views of the purpose of teaching a particular concept with a specific method. It is possible too, study the impact of decisions made in the classroom where teaching has no set prescription, but rather principles that can guide and improve their strategies in a permanent way.

(b) Sociocultural Dimension: Is about physics analysis placed in different situations and educational realities. This dimension encompasses skills through guide reflections about the meaning of setting a determined physics skill in various educational environments. Considering aspects such as learning styles of different types of students, current pedagogical trends such as those based on the science-technology-society perspective, and the importance of training in autonomy and reflection to be able to confront day-to-day problems that can arise in the profession, among others.

Thereby, students can be oriented to interrelate knowledge from other disciplines. Learning psychology to know how to adjust the level of complexity at which physical phenomena are studied. Language to research interaction strategies that ensure communication between classmates and teacher. Sociology, to understand behaviors of human groups and their motivations. Pedagogy, to enrich the possibilities of diverse teaching methods and classroom interaction. Education, to comprehend the "why" of curriculum organization and their objectives for teaching physics, among others.

(c) Interactional dimension: Is about enriching and qualifying classroom interaction. Pre-service teachers can be instructed in standards for energizing interaction and strengthening his intervention in the classroom. They can acquire skills for the use and creation of a range of resources that widen the scope of the processes by which he intends to reach the lesson objective and, simultaneously, broaden communication channels with the students, according to context and level of complexity of the scientific content.

This dimension should go beyond the understanding of the "technical" component in the profession of teaching, such as the use of a whiteboard, projector, or laboratory equipment; although these aspects should be considered. In this proposal, we work with different types of resources: the laboratory, technology resources, and bibliographic material.

Experimentation is approached from the different opportunities it offers. We characterized five typologies of experiments looking for development of thinking skills, the enrichment of language use, the forming of problems to be solved, the formulation and testing of hypothesis, the ways to represent data, and the technical requirements, among other aspects.

With regards to the use of information and communication technology, we understand that these resources require teachers to master the content they are to teach, master pedagogical methods, and, of course, master technology.

In the same way, the use of bibliographic material, enriched by technology was showed overcoming the short-sighted idea of using the textbook as a guide for the class and as the only literary genre to be introduced. We study available resources in virtual encyclopedias, research studies in physics and teaching physics, as well as scientific discoveries. Knowing that this material is not necessarily to be taken "raw" and directly to the class, but rather to constitute a source of inspiration and a foundation for class design, is essential.

In synthesis, we develop a didactic sequence such showed in table 1, whose data was mainly the written material produced by students on each exercise.

Table 1. Synthesis of the didactic sequence developed to take data.

Disciplinary dimension	Sociocultural dimension	Interactional dimension
- The open problem for philosophical reflection: falling bodies. - The use of history in a metacognitive exercise, the nature of light. - Study of epistemological profiles, the concept of time. - Meaning of "observation," "observables," and "the observer."	- Issues with physics teaching for diversity (adults, children, teens, blind people) - Reflecting on the STS perspective on the teaching of physics (analysis of different educational contexts) - The reflective and autonomous teacher (professional identity, ability to reflect for, on and from the teacher action)	- Use of typologies of experimentation (Home-made, demonstrative, Illustrative, virtual and, Mental). - Use of resources based on Information and Communication Technology (audio, video, software, stroboscope photography, among others). - Use of typologies of bibliographic material (science popularization, textbooks, research results in physics and teaching physics, virtual encyclopedia)

Data analysis

We analyzed after class, data obtained in each class, and we present the results of this study to the students at two times during the course to achieve feedback that would allow us to expand our comprehension of the results. Results were studied based on the perspective of Bardin (2001) who define the phases of pre-analysis, material exploration, inference, and interpretation.In each case, pre-analysis consisted of transcribing all student’s writings and organizing information by identifying divergences or convergences. We developed the phase of material exploration by defining emerging categories, for that was considering not only the content itself but the production context of the students' ideas. Finally, we make inference and interpretation by comparing the objectives of the general course according to our theoretical proposal with the student responses.

Results

We want to start by emphasizing that this research does not deal with how to teach physics but how to teach didactics of physics. For which, we develop a perspective of work in the classroom beyond the technical and instrumental vision, following modern currents of thought on didactics of science in teacher training. We also want to emphasize that our gain was not related to theorizing about what is didactic of science but to find ways to carry out the teaching of didactics, based on the design of three guiding axes to organize objectives, contents and teaching methodologies of the teaching of physics.

The most important result we can mention is the level of awareness of students to recognize the complexity of teaching physics. For most of them, at the beginning of the course, the exercise of preparing class consists primarily of remembering the contents and planning a sequence of concepts and problems with the help of the board, videos, and readings. At the end of this course, they had included in their speech ideas about the importance of metacognitive exercises, the meaning of treating physics in school contexts, the potential and limits of support resources in the classroom, the importance of alternative methods of evaluation different from the traditional written test, among other aspects.

They learned how to make reflections on their teaching service, what is the meaning of developing scientific thinking skills, both in their students and in themselves. Also, how to think about contents of physics contextualized to different teaching and learning conditions, what it means to develop learning processes, critical thinking, epistemological profiles, how to potentiate the laboratory practice by understanding typologies of experiments, among others as described below.

Another result to be highlighted is the interdisciplinary vision that students acquire about the physics teaching since they finally recognize the importance of social and human sciences to give alternative treatments to the physics, but they also make proposals to implement this knowledge in their future professional practice. At the beginning of the course, they talk about didactics and pedagogy as disjointed sciences of the reality of physics class, but little by little they build argumentations to adopt them in their speeches.

To present the results we will use the letter L to indicate the testimony of a student followed by a number that differentiates it from the other students.

Learning didactics from disciplinary dimension

By developing metacognitive-type exercises to make students aware of their mastery of physics, we found that students confront their conceptual difficulties in producing an explanation, right away they try to improve their language to talk about physics and then pass to foresee what could be done to enhance physics teaching. The design of these exercises was around contents of history, epistemology, and philosophy of physics as described below.

1.The use of history in a metacognitive exercise from the nature of light. This activity was designed taking information from (Silva & Martins, 2010). We deliver a sheet with names of authors which throughout the history of physics have made essential contributions to the definition of the nature of light, with their respective birth dates and nationality. Students were asked to work in a group to create a timeline, arranging the names in each year. See Figure 1. Later they were asked to make the hypothesis about the reason for the graphic's behavior.

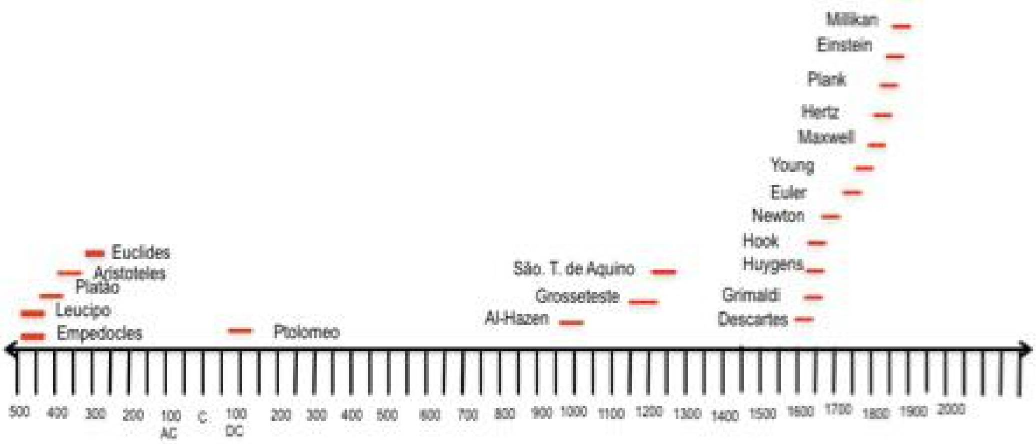

Figure 1. Timeline of authors who formulated definitions of the light nature [source: authors]

Students were surprised to observe discrete moments in the graphic since they had imagined that this process would have occurred on a continuum. This analysis allowed us to guide a discussion about the influence of different cultures, with an emphasis on religious, economic, political, technological, and experimental that impact scientific advances; and, simultaneously, allow us a review the concept of light, the physics teaching ideas, and visions of nature of science. Let's see some of the students' conclusions.

> *L3: "... This approach studied, and learned in class contributed quite significantly to me as a teacher, now I have a better basis to explain to my students how physics developed its concepts...*

> *L7: "... Knowledge of these theories helps to understand their history, helping to show to students how scientific knowledge evolves, ...they will see that theories are not genius things that appear in an instant."*

> *L14 "... This exercise gives the student a different view of science. It begins to realize that it does not behave linearly, it begins to demystify the question of absolute truth and increase its critical sense. "*

Next, we showed a sheet with a synthesis of definitions, which different physicist gave in his time about the nature of light, in which we observed that students had doubts or gaps in their knowledge about the meaning of the nature of light in different times. In the debate about results, they express different visions apparently similars about the light behavior like wave and corpuscle, but radically different in their definitions. They talk of light as a wave interacting with matter in wave and particle form, or wave whose corpuscle behavior occurs in the way of groups of waves propagating but interact with the matter as a particle, or light propagating as an electromagnetic wave or as a particle depending on the situation. They were surprised to see the diversity of ways of understanding the nature of light, and conclude that it is necessary to understand their knowledge about physics concepts.

2. Study of epistemological profiles, the concept of time. We gave a questionnaire based on the work of (Martins & Pacca, 2005) which addresses the Bachelard's epistemological profiles for the concept of time, and (Disalle, 2006) which explores the time concept. Students were asked to work individually and to draw on a blank sheet of paper everything that they associated with the word "time," and later to answer questions such as:

(1) Does time sometimes speed up or slow down?

(2) How do you perceive that time passes?

(3) Does time exist without a clock?

(4) Does time exist without human beings?

After that, each group got a set of answered questionnaires with a guide for the analysis of these answers, which contained study categories related to the four epistemological profiles (simple realism, empiricism, traditional rationalism, and surrationalism). Reflections on this point were of the type,

> *L13: "In the analysis of the epistemological profiles there is a predominance of simple realism. It was evident the absence of traditional rationalism and surrationalism, these results are extremely worrying, being that the research was carried out with students of the last year of the physics course.*

Students discovered that everyone has all the profiles but in different levels and reflect on how to reduce the intensity of simple realism profile in their thought. They also reflect on how to improve learning process of this concept, and in general of physics from an epistemological perspective.

3. Meaning of "observation," "observables," and "the observer." The first part of this activity we based on (Author, 2009). We seated the group in a circle and distributed a tree leaf, after was asked to the students to "observe" and describe the leaf individually, developing a dynamic in which everyone had the opportunity to read comparatively the descriptions of their classmates.

The exercise created awareness of how the act of "observation" is much more than "seeing" with the eyes and implies the use of previous knowledge, requires intensity, calls for "seeing" with all the senses, and leads to an interdisciplinary nature.

For the second part, we used (Pessoa Junior, 1992) as a reference to define the topic. We asked the students to work in groups to establish the absolute limit between the large and the small into nature. Students, in general, associate "the large" with macro related to human scale and "the small" with micro scale. But, right away they saw the problem about what would be the appropriate language to describe the large and the small, as well as the difficulty in identifying what would be observable or not, and measurable or not. Let's see some responses from groups (G)

> *G1: "When we cannot observe with a microscope of lenses with the best resolution, we can consider a border between the" big "and the" small. " Where the nonobservable would be "small" and the "big" observable.*

> *G2: "In human perception, we can say that small and large limits are defined from the scale of human being, so smaller objects than the human being (our perception) are considered smaller... "*

> *G3: "We consider that... in nature, the limit between the big and the small is related to the vision at naked eye. That is, we consider big what we can observe at naked eye, and what we just can observe with the aid of measuring instruments, we consider small. "*

Thus, with reflections from the individual to the collective, socialization and co-evaluation, we conclude together that "observing" is not an action developed in a single moment. But is a process in which it is necessary to have clarity about the intention of "observing something" which can provide information on the characteristics system to be observed, the theoretical assumptions of observation, the instruments, and the appropriate and enough language for the respective description.

They also reflect on how to know what exactly they observed when studying physics phenomenon. This debate was aimed at the quantum theory regarding the macro and the micro, they asked about the instruments that allow observing something when it cannot be seen with the naked eye and how to build explanatory models for it.

In conclusion, this dimension guide to students to reflect on their knowledge about physics independently of equations domain, more related to their scientific language and educational intentions. Students found it is essential to know and recognize the history of concepts with their authors, cultures, political moments, language, and technological developments, etc. Regarding epistemological and philosophical exercises, they discovered their potentialities and shortcomings in their scientific language and how they construct their explanatory models reflecting about their epistemological profiles and discussing what they observe when they study a physical phenomenon.

So, they asked themselves if they understand the physics they are going to teach. We consider this aspect as very important because this is the first step to an adequate didactic design. Now, students were ready to think for whom they will teach their physics.

Learning didactics from Sociocultural Dimension

In this phase, we focus on accompanying students in an analysis of different educational contexts. They recognize that didactic transposition or scientific content adaptation to a specific context is not a simple act of increasing or decreasing equations to make it simpler. The adjustments must consider the sense given to the physics learning and requires work constructing language, studying physical phenomena at different levels of complexity to be taught from a child to adult audience and from the formal to the informal education. They also noticed the importance of studying different interaction methods in the classroom and concluded they have become aware of how much they still need to learn to teach physics.

The design of these exercises was around perspectives based on social and human sciences about multiculturality, relationships between science, technology, and society (STS) and, reflective teacher, as described below.

1. Teaching physics for diversity. Based on the works of (Author, 2010); (Fracalanza, Amaral, & Gouveia, 1987); (Ferreira & Zimmermann, 2009); (Silva & Terrazzan, 2011). We elaborated a project representing the main difficulties in teaching sciences to children, youngers, blind people, and adults. After studying this situations, students reflect on how to overcome these barriers. Below we present all the obstacles identified by the students under the different learning conditions, which we analyze individually to show the students it is possible to overcome them whenever an investigative attitude is assumed in each case.

Teacher's unpreparedness.

Lack of proper lesson planning.

The oral communication.

Difficulty in identifying learning styles and pre-conceptions.

Lack of resources to connect sciences with the student's daily life.

Lack of more critical sense to position themselves in front of the situations of society.

Teaching based on simplified contents.

Teacher`s intolerance with student's questions.

Lack of knowledge about the use of analogies.

Difficulty to choose correct representations to exemplify or illustrate phenomena.

Little preparation to solve student's doubts.

They reflect about the education they are receiving is to teach regular students in a regular school within a specific behaviour pattern, and the rest will be learned directly from experience. But they comprehended the importance of prepare classes from research results because there are many people showing experiences and new perspectives that can help to assume physics teaching for diversity in their future pedagogical practice.

2. Reflecting on the STS perspective for physics teaching. We examined why this view can have diverse objectives, such as education for citizens, the use of technological applications, scientific literacy, etc., each with its pros and cons, based on works such as (Vazquez, et al 2012). We work on a case of recent news about the creation of technologies for environment care, a news report about the Brazilian senate law regarding environmental policy, and scientific documents explaining the reasons for global warming.

Students found that topics such as energy, heat, optics, and electromagnetic radiation could be taught in conjunction with problem-solving. For example: analyzing the efficiency of different forms of energy production regarding cost-benefit and environmental impact; studying the relationship between food production, the energy consumed in the process and the energy offered to the consumer; and holding debates over political decisions on the topic, among others.

These are problems which, from their point of view, will make education beyond conceptual learning, to use critical thinking, reasoning, dialogue, and other thinking skills. They also call for introducing qualitative evaluation processes, with indicators such as "commitment," "degree of participation," "contribution to the discussion," among others. Below we present the general students' perceptions about the power of this perspective in class.

- To deepen in knowledge of physics concepts,

- Analyze causes and consequences of the phenomena,

-Relate Physics knowledge with social and technological problems,

- Understand the reality in which we live, in its political, cultural, social, environmental and technological dimensions,

- Integrate diverse contents to understand a problematic better.

- Encourage curiosity and critical positioning,

- Analyze the possibilities offered by physics in solving problems.

3. The reflective and autonomous teacher. We seek to educate for self-reflection on the teacher's practice. For that, we use a theoretical foundation the works of (Alarcão & Moreira, 1993); (Copello & Sanmartí, 2001); (Nóvoa, 2007); (Zeichner, 1986)) who invite us to consider reflection as a means of innovation in teaching methods.

We elaborated six narratives based on the teaching experience by the researcher. They were problematic or uncomfortable situations, narrated only up to the point where an immediate decision was needed to solve the problem. We asked the students to imagine themselves in this hypothetical situation and to make choices. Example of narrative: Subject: Physics (Mechanics)

Age range: 14 to 16 years (Secondary education)

Public school

...I was giving a class on "the falling of bodies," when in one part of the explanation, I decided to make a better illustration of the subject and to let a pencil and a wooden eraser fall to the floor. I asked the students if, by allowing them to fall at the same time and from the same height, the objects would hit the floor at the same time. Some of them responded that they would; others, that the pencil would hit the floor first; and others, that the eraser would hit first. One student said that the objects were very close to the floor and offered to drop them from a higher position above the table. Meanwhile, all of them continued to answer as they initially responded. Then someone said that it would be better to let them fall from the classroom window (it was on the fourth floor of the building), so I had the idea to drop the objects from the railing of the hallway across from the school's playground. I divided the class into small groups—half of them would go to drop the objects and the other half would go to observe them fall to the ground in the playground. Everything was going well until some of them began running on the stairs. One student dropped, and another student decided to take advantage of the opportunity to look for his brother in another classroom. The students on the playground were anxious, shouting loudly and betting on the same conclusions they had given in the classroom; and there was a lot of wind, so the students went to look for more massive objects. The chaos ended up generating complaints to the Academic Coordination of the school. It was then that the coordinator called me out to ask what was happening, and asked me to take the students back to the classroom and continue with my activities inside.

My answer to the coordinator was… What I told the students was…My answer to the coordinator was… What I told the students was…

Because of the material nature, and with the purpose of favoring individual and mental reading, as well as, decision-making in each situation, we designed the clock activity, which implied exchanging material and presenting the decision to a group of classmates. We observed recognition by the students about it is possible and necessary to improve teacher's intervention in class, beyond the mere study of physics, which highlight the complexity of the teaching role. However, in several cases, reflection is not understood as a possibility of preparation for action or self-evaluation, neither a method study on one's teaching practice.

In working with this sociocultural dimension, we provoked curiosity concerning how to solve problems of content adaptation and of teaching methods for different situations and educational realities, which implies an interrelation of diverse academic disciplines, going beyond the attitude of expecting that the future teachers learn to teach solely from experience. It was also possible to widen students' mentality, the panorama of options of class work, and, at the same time, orient them toward the reorganization of their physics knowledge when thinking in teaching process with diverse learning objectives.

In conclusion, there was an acknowledgment of teaching complexity regarding ways to improve or potentiate the interaction between actors in the classroom; it also contributed improving the discourse respect specificities of teaching physics in different contexts. Let's see a response shared by the students when asked them about what they learned from this set of exercises

> *L_{11}: "(..) throughout the classes what struck me most was that the profession of teacher is very complex, and leads the teacher to face unexpected situations. But I realized that the way to approach these themes with groups and discussion was very productive and profitable...*

Interactional Dimension

1. Experiments Typologies.

We designed a sequence of at least five different ways of using experimentation. Inspired by the works of (Sanmartí, Marquez, & García, 2002); (Séré, Coelho, & Nunes, 2003)) who defend experimentation as a method that permits relationships between concepts, objects, and symbolic language.

We characterized experiment typologies according to the procedures in the classroom they make possible, being (1) Mental experiment about Einstein's elevator, in which the student is caused to make logical deductions based on comprehension of the theory showed in an aside from book of (Einstein & Infield, 1938). (2) The illustrative experiment of the Newton disk, through which we developed a discussion around what is evident or not, observable or not when the disc turns; and, what was possible to explain with their physics knowledge. (3) Checking a law; exactly acceleration of gravity. For this experiment, we used a simple pendulum, where students had to gather and analyze data to prove the theory. (4) Home-made experiment, involving the construction of a "mechanical tractor" based on the work of (Author, 2012). For this, we offered materials and a model for students to build and test to improve the assembly quality.

After group discussion of these results, we developed reflections which showed the recognition of methods richness offered by the resource of experimentation to educate thinking skills. For example, to analyzing, explaining, systematically observing, asking questions, discussing, studying variables, and verifying, among others, going beyond merely corroborating a theory or captivating the students. They said, for example,

> *L3: The characterization of the experiments and the classification showed in class, allowed me to clarify several doubts about my teaching physics method. The way of approaching different experimental typologies can generate clarification in the students' thinking, that is why to join different types of experiment with kinds of representation and the appropriate words at the moment of explaining, can generate an excellent relationship between students and teachers.*

> *L7: It was interesting to see how we cannot differentiate, for example, variables from parameters, and this helps us to understand better how to teach. In the different types of experiments, we saw a variety of aspects that we can work in addition to the content, such as produce explanations, argue, formulate a hypothesis, observe, analyze, and all that...*

2.Use of information and communication technology (ICT).

We use technological resources such as (1) Audio stories, in which we present material prepared by (Author, 2010) with the story "The Last Question" by Isaac Asimov. (2) The video, in which we took a video of (Author, 2010) of two minutes long where we observed the production of sound through percussion, wind instruments, and strings. (3) Stroboscope photography without flash. We take pictures of an object in free fall, obtaining explanations. (4) Interactive math software. Using the software "Geogebra," we created an activity based on the work of (Author,

2010) in which we studied the behavior of the simple pendulum; (5) online evaluation software. Using free software to generate online questionnaires, we assign the elaboration of seven types of questions related to a physics concept.

Students conclude that more research is necessary on the interactions between students and teachers through the computer, evaluating their real limitations and possibilities and recognizing the classroom space as a network for interactive dialogue. Students analyzed opportunities for their use in teaching physics concepts in different contexts. In each case, self-evaluation and co-evaluation were applied using indicators with qualitative ratings.

> *L9: I did not know that you could work with audio or photo material to teach physics. I thought everything about ICTs was on the computer. I also learned that the software of something is not enough, it is necessary that we as teachers plan what to do with this, to work a concept correctly...*

> *L1: This was the first subject in the course that worked aspects that future teachers need, such as: - knowing the students' and our conceptions and knowing how to work to improve teaching; - Discuss new technologies for teaching; - Perform simple experiments for teaching; - Etc. All of these aspects operated as if it were the students themselves (us) working as teachers. It contributed so much to our conceptual maturation.*

3.Use of bibliographic material.

We set up five types of bibliographic resources, all of them dealing with the same topic of "movement." We distributed books, papers, journals to each student along with a study guide, in which they were to identify the author, year, and type of material; and, to write a summary, study the information presented, and explain its use for teaching the topic in a specific context. Next, those who had the same type of material formed discussion groups to share their conclusions.

Materials used were (1) Science popularization, under the heading "The Enigma of Movement" of the book "The Evolution of Physics" by (Einstein & Infield, 1938). (2) Textbooks, using the book page presentation and the chapter about the movement from two physics textbooks. (3) Research results in Teaching Physics, with an aside from the book "Reasoning in Physics" by (Viennot, 2004), which describes and analyzes a survey given to university students about ideas of the movement. (4) Virtual encyclopedia, using some definitions from "Wikipedia" concerning "movement." (5) Research results in Physics, using the preface of the book "Principles of Mechanics" by (Hertz, 1899).

In general, there was recognition of the diversity of bibliographic material and its different potential according to a need for teaching and learning. Some things that became clear were the different options for studying a particular subject, the different ways to approach the complexity and language of concepts, the various methods for creating didactic sequences, and above all, the importance of the teacher's objectives upon taking over the classroom. They identified the following uses, to approach the problem in an introductory manner and then complement it with other processes;

- *To know the history of the concept from the original authors,*
- *As a source of reading and reflection for the preparation of the class,*
- *As inspiration to extract some sections that one can use in class,*

- *As a material to be analyzed and criticized together with the students,*
- *To overcome the conceptual errors contained in the books,*
- *To read with the students,*
- *To generate debate on controversial issues.*

In the Interactional Dimension, it was possible to overcome the conventional view that use of supporting resources in the classroom is in itself a solution to the various problems in teaching, or that the creation of these supporting materials would be an end in itself in the Didactics of Physics.

We were able to elaborate upon the understanding of technological, bibliographical, and laboratory resources in conjunction with content mastery specific to Physics, and the intensity of classroom interaction, to reach educational objectives.

Finally, students evaluated this course and said;

> *L11: This discipline was very well elaborated in all aspects because the methodology used, helped a lot to reflect on the teaching where I could learn from my own mistakes and doubts when I had to explain some physical concepts. I could see where I am faulty and have to improve my performance as a teacher...*

> *L7: The knowledge of different methodologies than traditional was significant for my training.*

> *L6: Through the course, I was able to understand the aspects of science better and how to teach it, to improve students' classes, interest and learning, achieving better learning outcomes*

> *L3: The application of didactic methodology in ourselves, that is, the reproduction of the Didactic proposals of the articles, making it possible to learn these methods more efficiently than if I had just read the articles. The activity of positioning ourselves in complex moments that the teacher passed, provided us with practical reflections on the attitudes we may need to take. Such things give us a less theoretical and more realistic education.*

> *L10: The discipline provided interaction with various materials and resources to improve classroom teaching. He developed critical thinking regarding the uses of methodologies. The classroom activities were entirely satisfactory. There was active participation of the students.*

Conclusions

We know all these perspectives that students developed are already well documented in the literature, and many of them even surpassed by new perspectives. However, the exciting thing about the result is the fact that they reach these conclusions under our guidance, but autonomously. It was possible through exercises designed from a structure based on three dimensions that gradually lead them to reflect first of all on themselves, then, on the action of teaching to someone, and finally on possibilities of enriching interaction in the classroom. Finally, the strategy allows them to build an identity with the teaching profession, and a marked interest in designing physics teaching methodologies different from those they know.

Respect the question about how can we harness the various disciplines when teaching Physics Education? We conclude that two factors should be combined to be able to arrange objectives, contents, and methodology to teach

Didactics of Physics. First, it is essential to have a structure that allows progressive content organization for course development. The second is to acknowledge research results in the subject area selected based on requirements of the proposed structure, with the criteria that they are from research areas that study relationships between diverse academic fields to solve problems in physics teaching.

About the questions of What kind of activities is most appropriate to achieve an interdisciplinary focus in Physics Education? And How can we go from simple to complex, or from primary levels to higher levels in teaching Didactics of Physics? We conclude that the three suggested dimensions (disciplinary, sociocultural, and interactional) allow the future teacher to be guided progressively, based on his own (re)cognition of Physics knowledge. Then, students will be able to think of how to adapt such knowledge to teaching processes in different contexts and, finally, be able to reflect on the support resources that would most appropriately meet the objectives, which forms specific teaching skills and promotes professional growth.

Upon observing and comparing student responses, as the course progressed, we found that they improved their critical thinking skills for the topics studied. For example, at the beginning of the course, the majority defined the Didactics of Physics as a set of educational support tools and considered History and the Philosophy of Physics as resources to "captivate" students. These ideas gradually changed during the course, so that at the end, they expressed that History, Epistemology, and the Philosophy of Science served the purpose of helping them reach a greater understanding of what they teach, and, at the same time, allow them to enrich their planning of teaching strategies. We can conclude that there was an evolution of students' ideological views concerning what they consider achievement in the Didactics of Physics, with the purpose of enriching processes of teaching and learning.

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