

Establishing common elements among some science education references as a resource to design a Didactics of Physics program for teachers' initial education



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(Received 30 August 2011; accepted 5 November 2011)

Abstract

We present a first step of a research designed to think a didactics of physics by establishing common elements among science education researchers' productions. The first step was to select and characterize some important referential recognized by the UNESP' Science Education Research Group as important references in the science education literature. These authors are from different countries, with national and/or international recognition, like: Astolfi, J. P.; Cachapuz, A.; Gil Perez, D.; Sanmartí, N.; Tardif, M.; Nardi, R.; Viennot, L. It was, then, elaborated a bibliometrics analysis, in order to identify the references they employ in their researches, and the context in which the literature were produced. We analyzed afterwards their production and elaborated a summary table; we found they present research results in the last decades. This material was analyzed under the category "common elements showed by the authors", turning up elements such as; research on science teachers initial education; the importance of research in science teaching; and the use of the term "Didactics" and its meaning in teaching and learning processes. Matching the authors' perspectives in the presence of these topics, we found a range of subtopics, such as; the necessity to graduated research teachers, the science education research and its impact in science teaching, the didactics of science as a field; the functions of courses about human science on curricula, among others. From the common subjects among the authors we will try to answer some questions: a) How should be understood the discipline "didactics of science"? b) What role should play the didactics of science in teachers' initial education? c) What must know a future science teacher? Finally we will try to draw some conclusions in order to design a Didactics of Physics program.

Keywords: Physics Teaching; Didactics of Physics; Research in Physics Teaching; Content Analysis.

Resumen

Presentamos la primera parte de una investigación destinada a pensar la didáctica de la Física, la cual consistió en establecer elementos comunes entre algunas producciones de investigación en enseñanza de las ciencias. El primer paso fue seleccionar y caracterizar algunos importantes referenciales, reconocidos en el Grupo de investigación en Enseñanza de las Ciencias de la UNESP, como referencias relevantes en la literatura de la educación en ciencias. Estos autores son de diferentes países, con reconocimiento nacional y/o internacional, siendo ellos; Astolfi, J. P., Cachapuz, A., Gil Perez, D., Sanmartí, N., Tardif, M., Nardi, R., Viennot, L. Fue realizado un análisis bibliométrico con el fin de identificar los marcos referenciales utilizados por los investigadores, tanto como el contexto en el cual fue producida tal literatura. Posteriormente analizamos su producción y elaboramos un cuadro resumen, encontrando que presentan resultados de investigaciones realizadas en las últimas décadas. Este material fue analizado bajo la categoría "elementos comunes presentados por los autores" de donde surgieron aspectos como; la investigación en la formación inicial de profesores de ciencias, la importancia de la investigación en enseñanza de las ciencias, y el uso del término "didáctica" con su significado en los procesos de enseñanza y aprendizaje. Combinando las diferentes perspectivas de los autores bajo estos tópicos, encontramos una gama de subtemas, tales como; la necesidad de formar profesores para la investigación, la investigación en educación y su impacto en la formación de profesores, la didáctica de las ciencias como un campo, la función de los cursos de ciencias humanas en los currículos, entre otros. Con base en estos tópicos comunes trabajados por los autores, intentamos responder algunas preguntas: a) ¿Qué debe saber un futuro profesor de ciencias?, b) ¿Cómo debería ser entendida la didáctica de las ciencias? c) ¿Que rol juega la didáctica de las ciencias en la formación inicial de profesores?. Finalmente esbozamos algunas conclusiones que permiten pensar un programa de Didáctica de la Física.

I. INTRODUCTION

Using content analysis as research technique, we have done a review of seven science education books, extracting the main ideas exposed. With this information we developed a summary table, in order to compare their authors' main ideas. After, we applied the analysis category "common elements showed by the authors", getting relationships between them, and attempting to take the proposals as a whole. We found that authors make an urgent call about the need; to redesign teachers' initial education programs, to strengthen both, science education research and training research science teachers, and, in most of the authors, to characterize the didactics of science.

The research methodology considered perspectives of writers such as Bardin, L. [1], and Flick, U [2], who exhibit qualitative research techniques, which allow us to do inferences by studying documents in a systematic way, and to identify specific features within a text. In the same way, authors such as Albert, M. J. [3], and Rodriguez, *et al.* [4] who focus this kind of research on education's scope, as a strategy in the ongoing pursuit of knowledge, working issues and problems related to the nature, epistemology, methodology, aims and objectives of education.

Furthermore, in order to know support ideologies (SI) in the works, we performed a bibliometric study looking to highest frequency of citations and, analyzing its intent and content. In this study, we choose references cited an important amount of times throughout the text (more than three, four, or five different times, dependent on the book), without taking into account self-references, because for them, we did a separate count, which allowed us to know the original research on which author based their productions. The reader will find in this paper, statements from the summary table, which are not literal author's expressions, however, represent their proposals. It is important announce too, original summary tables are not placed here, due to the permitted article size.

Results about common topics worked by the different authors, can be summarized in such aspects as: a) reviewing curricula for science teachers under interdisciplinary perspectives, taking all kind of knowledge which would be required to solve own science teaching problems, b) Training research teachers through a series of skills to do research in didactics of science, and, c) Assuming didactics of science as an autonomous discipline, that allow us to articulate different knowledge in education of science teachers.

II. CHARACTERIZATION AND ANALYSIS

A. Brief description

In Table I can be seen; basic information from the book, a brief description, and, support ideologies (SI) for each of the works analyzed. The numbers in parentheses represent amount of references used by the authors, and, percentage of self-references. Initials in parentheses will represent the authors throughout the paper.

We observed that most of the references consulted by the authors, are on average, from the 90's (46%), followed by the 80's (35%) and a smaller number from previous years, including classics in various areas. It means that, these group of works, were produced within the context of consolidation of science teaching as a specific field, which began in the 60's and had a large increase since 90's, according to Fensham [12].

TABLE I. Title, authors and their nationality, year of production, amount of references, self-references percentage, brief description, and support ideology.

<p>A Didática das Ciências. Jean Pierre Astolfi, Michael Develay. [5], 1989. 6th Ed. 2001. France. (20 references, 10% self-references). (AD)</p> <p>They present an epistemological-didactics reflection based on Physics and Biology history, in order to propose a new vision about teaching and learning process.</p> <p><i>SI:</i> They take Bachelard's input on epistemological obstacles, and the contribution of Piaget as a starting point for the idea of "representations". They characterize didactics of science, raised by; Chevallard, who rejects anachronism on knowledge taught, Martinand who introduces a socio-cultural perspective of science education, Sanner who studies processes in the construction of scientific knowledge, and, Giordan who researchs on teaching biology.</p>
<p>Ciência, Educação em ciência e Ensino das ciências. Antonio Cachapuz, João Praia, Manuela Jorge. [6]. 2002. Portugal. (249, 8%). (CPJ)</p> <p>It is an analysis of topics related to the basis, characterization and evolution of science education in recent decades, aiming to contribute to its theoretical basis, and describing the most important perspectives on science teaching.</p> <p><i>SI:</i> Vygotsky as precursor of constructivism, who emphasizes the influence of socio-cultural factors in learning, which is complemented by Ziman and Morin, who see science as a dynamic activity with science-technology-society (STS) relationships in their teaching. The need to link history, philosophy, epistemology and science education in teaching and teacher training, with authors such as Duschl, Mathews, Gil, D.</p>
<p>Formação de professores de ciências. Daniel Gil Perez, Ana M. Pessoa de Carvalho. [7]. 1993. Spain-Brazil. (167, 28%). (GC)</p> <p>They show the need to train teachers in knowledge such as; rupture with simplistic views, awareness of what is taught,</p>

challenge "common sense" ideas about teaching, specific knowledge for teach, advise, assess, and, correlate didactic research with teaching.

SI: They introduce the idea of "common sense" of the teaching profession, and the convenience to overcome it, relying on authors like Furió, and, Hewson, P., Hewson, M. Also, critique the sum of scientific knowledge with a psycho-pedagogical complement in training of science teachers, according to Mcdermont, Krasilchick, and others. They take Bachelard on "epistemological obstacles", whose treatment is considered an important outcome of research in didactics of science, according to Driver, and others.

Educação em ciências. Roberto Nardi (org). [8]. 2001. 4th Ed. 2010. Brazil. (200, 6%). (N)

They work in topics like; contents in the graduation as a resource rather than as a goal, science as a process rather than as a product, conceptions of science teaching, the perspective STS, physics for blind people, the sense of teaching and learning sciences.

SI: Teacher's role and diverse dimensions of the classroom, according to Villani. Analysis about teaching practices based on Freitas, Souto, and others. The relationship between citizenship and teaching on authors like Bicudo, and, Fourez. Analysis and proposals from the psychology of learning by Piaget and Vygotsky. Current proposals for innovation in classroom with authors such as, Gil Perez, Glagiardi, Camargo. Design of learning processes from different perspectives to the traditional with authors like Zanetic, Duschl, Guston or Machado.

Didáctica de las ciencias en La educación secundaria obligatoria. Neus Sanmartí. [9]. 2002. Spain. (64, 3%). (S)

She reflects on the nature of science, makes a call to relate several proposals about the purpose of teaching science, and, proposes criteria to decide what to teach in science, and how this teaching may be appropriate within new contexts.

SI: She examines the development of constructivism and its impact on emergence and characterization of didactics of sciences, through Piaget, Vygotsky, Novak, Ausubel, and Jhonson-Laird. Also, she works new perspectives of science education (STS, transversal projects, structural concepts, use of history, philosophy and epistemology) according with authors such as, Izquierdo, Gil, D., Duschl, among others. She studies didactics of science and the need to improve science education, with authors like Astolfi and Claxton.

O trabalho docente. Maurice Tardif, Claude Lessard. [10]. 2005. Canada. (433, 4.6%). (TL)

They collected the most important research from the last two decades, at least in the francophone, Anglo-Saxon and Latin American countries, about characterization of teaching as a "human work" done by, and, for humans, and with "interaction" in the center of the practice teaching.

SI: The complexity of teaching work, grounded in authors such as Gauthier and Doyle. The teacher's knowledge according to Shulman and Tochon. Several own studies and investigations about the realities of everyday life of teachers, and school's organization. Duran, Schon and Hargreaves let them think the school from diverse perspectives, and, in different times. They work classic authors such as Foucault who analyzes school's world, and, Habermas who enters the conception of "interaction" on the work.

Reasoning in Physics. Laurence Viennot. [11]. 2004. France. (133, 17%). (V)

This book is the union of several results from research developed throughout many years, on the natural reasoning in physics. She characterizes natural reasoning and establishes its relationship with education's purposes, in order to do pedagogical suggestions that could guide teaching strategies, different from the traditional.

SI: She develops an analysis and critique of both, Piaget and

Bachelard's proposals, considering them as precursors in education research. She bases her proposal on several works conducted in conjunction with authors such as; Closset, Rozier, Maurine, Saltiel, Driver, Chaveut, among others, who work in surveys on the classroom about different physics concepts, trying to recognize misconceptions and reasoning ways.

B. Common elements showed by the authors

We found three recurrent topics in the works; it doesn't means authors not talk about other themes. These topics are:

1. *Initial Teacher Education (ITE)*; which is discussed in three sub-themes.

The first has to do with disciplinary fields that must be included in the curriculum, which can be consolidated in this way; (AD) refers to didactic of science, (CPJ) refers to epistemology, history of science and psychology of learning, (GC) refers to specific didactics, pedagogy, psychology, (N) refers to research in the area, (S) refers to the epistemology and philosophy of science. Furthermore, most coincide with the perspective of (CPJ) on take this knowledge with inter- and transdisciplinary sense, not as isolated groups of specific knowledge.

The second theme is about knowledge that the teacher should get in their initial training. (AD) said, should be in four variables that makeup didactic of science, such as; learn to communicate, domain of concepts networks, reflection didactically, and choose a pedagogical model. (GC) said, knowing how to apply the curriculum. (N) said, be aware of their role, be reflective and critical, articulate their work with social and political implications. (S) said, reflect on what to teach, how to teach, and how to achieve the learning. (TL) said, be aware that, interaction is at the center of his work. (V) said, not just become identifying mistakes, but look forward to new teaching strategies in understanding natural reasoning on Physics.

The third theme refers to questions that should be answered, in order to reform the curricula. Questions like; (CPJ) what is the purpose in teaching science, and, why?, (GC) how to correlate results of research in the area and initial training teachers?, (N) what kind of strategies are necessary to turn contents into a resource rather than an educational objective?, (TL) how to avoid teachers having to learn their job *in locus*, and became professionals at the university?

2) *Relationship between research & teaching.* From their different perspectives, all authors conclude that it is necessary, both, training for to do research and to do research. About research on initial education, they present different proposals. (AD) and (GC) suggested to train future teachers to explore topics such as; the subject content which they will teach, and, learning processes in themselves and their future students, (V) suggested to teach them to interpret natural reasoning trends that learners have on some phenomena, (AD) and (TL) suggested to teach organization's school with its objectives, results, tensions and challenges, (AD), (GC) and (N), suggested to train for

reflection on didactics, and, on new perspectives about teaching, in order to go beyond the "common sense" on teaching. Students should be able to assume the didactic of science as an articulate axis between science and teaching science. It means future teachers must acquire skills to research in this field, with metacognitive abilities and reflective attitude, rather than, acquire simplistic perspectives on science teaching.

On the other hand, we observed that authors are optimistic on educational transformations, whenever, teaching practice and research become inseparable, as said (GC). According to (S), research is an appropriate way to interrelate scholar science, teachers act, and, students' processes. In the same line, (V) said, escape from traditional education implies to create new strategies under comprehension of reasoning processes. However, (TL) warn that research conducted by the academy on teachers at school, or by school teachers about their work, should include measurable facts, but also processes, tensions, challenges and dilemmas that teachers face day by day, these aspects are often not considered, which generates unreal information.

The authors also tell us, that teachers will be recognized as professionals when educational research been affected social contexts, and its aims responds to current issues. For example, (CPJ) propose the Science-Technology-Society-Environment –STSE- as a guiding perspective of sustainable change to the current realities, in (N) we can see a tendency to research aimed at producing innovations in schools, whose advantage be to increase the meaningful to all stakeholders in the community, as well as, the inclusion of all actors in learning process. According to (GC) there is a need to relate academic research with teacher's job, which implies to think teaching as a research field that resolves proper problems to the school. In addition, we infer from (TL), that results of educational research should contribute to achieving recognition of "teaching work" as a "human work" done by, and for humans, and, with vital importance to society.

3) *The use of the term "Didactics" and its meaning in teaching and learning science.* We can summarize the characterization of "Didactics" by the authors, as a disciplinary field that picks up other disciplinary fields in order to solve classroom problems, and, with its own objectives and action scope. In consequence, specific didactics become necessities.

(AD), (N) and (CPJ) agree with take the didactic of science as an autonomous discipline, that uses knowledge from pedagogy, epistemology, history of science, psychology, and, sociology. However (GC) extend to all knowledge necessary in order to solve particular problems about initial training of science teacher.

The reason why is impossible to assume "Didactics of science" as a branch of another discipline, is because its scope works with particular facts on education, requiring interdisciplinary knowledge, facts such as; (AD) classroom situations, students' representation, interaction ways between teachers and students, (CPJ) innovation of teacher's strategies, (S) criteria for choose content,

generation of models and appropriate practices to each kind of context, (TL) teaching of science knowledge, with particular forms, and designed specifically for students education, (V) make students learn with greater understanding and consistency.

Consequently with the above, we can say, didactic of science allow us to establish a link between, knowledge produced by science, problems of society, and, people training through science learning. Thus, develop teaching practices is determined by specific content worked, resulting on specific didactics, but, taking care some dangers warned by (AD), about don't get a "general didactic" that just talk about educational theory, neither get "specific didactics" just worried by scientific content.

III. ANSWERING RESEARCH QUESTIONS

A. How should be understood the discipline "Didactics of Science"?

It is a field of knowledge, which has its own theoretical framework, its study objects, and research methodologies. Thus, production of knowledge in didactics of science happens when researchers solve problems related to the school and processes on teaching and learning science. Its theoretical framework is supported by scientific knowledge of physics, chemistry and biology, but too, in other areas that help understanding school events. Its study objects can be ranked into three groups; curricula and its application, knowledge to be taught, and, learning-teaching processes of students, but all of these mediated by interaction between teachers and students within particular contexts.

B. What role should play the didactics of science in teachers' initial education?

It should allow us to articulate different scholars spaces that make up the training program, and, also should allow students to solve teaching and learning problems, using diverse kinds of knowledge. The didactics of science should be responsible for inserting into their content and, their teaching methods, research results and trend analysis of teaching, in constantly updating. In this way, it is possible to produce professionals more conscious of their role and knower of research results in the area.

C. What must know a future science teacher?

Beginner's teachers in teaching science should know first of all, that their profession is mainly a "human" work. Thus, they will have to rebuild interactions strategies with their students, as well as, their colleagues, superiors, and environment. Therefore, future teachers need to learn a knowledge network for science teaching, rather than a simple accumulation of knowledge isolated from various disciplines. In consequence, they have to identify clearly, what didactics of science is, and recognize its scope, subjects and research methodologies. It means, didactics of

science should be taught in order to train students to analyze and understand, at least, the goals of teaching science in context, their own domain on science contents, and, learning-teaching processes.

IV. THINKING DIDACTICS OF PHYSICS IN TRAINING PHYSICS TEACHERS

Then, we can infer, it is important to have an academic space named "Didactics of Physics" or something similar, within training courses for physics teachers, in order to link physics knowledge with disciplines from human science, and, in this way, teach students to solve own problems of physics teaching.

This academic space could develop topics like tell us, for example, (V) on generating strategies to overcome natural reasoning on physics phenomena, but it means, teachers have to guide the construction of coherence on explanations of physics facts. Also, in this space, we can teach how to choose and consider knowledge from human science on physics teaching, as show us for example (AD), (N) and (CPJ), who propose using the epistemology to identify epistemological obstacles (conceptual, psychological, ideological), and formulating "problems" for the class work. Or, reflecting about what is "observe" in the world of physics. Or, using history of physics to study discoveries in context, to think on what is a "discovery", or to establish parallels with students' misconceptions.

Didactics of physics can use, too, knowledge from psychology of learning, sociology, and education, in order to construct pedagogical practices, and, in consequence, improve the interaction in classroom. Or, according with (N) should include a decision to apply knowledge of moral and ethics, for students to constitute their truths responsibly.

Create a new subject into the curriculum, is an option. However, this academic space about "didactics of physics" can be developed as an articulate axis between different disciplines, or, can orientate transformations on methodologies and themes in current undergraduate programs.

V. CONCLUSIONS

After doing content analysis on the results of these seven authors, we found strong evidence for considering that nowadays there is an urgent necessity to think science teaching in another basis. The authors provide enough elements to start this change, from different fields, such as, renewal curricula of science teaching, research in education, interaction between research and teaching, reflection on goals of science education in different

education levels, interaction between research community and educational politics.

The authors present more coincidences than differences. A major coincidence has to do with the improvement of science education, integrating knowledge from other disciplinary fields, such as, epistemology, philosophy and history of science, psychology of learning, pedagogy, and educational politics. Being so the field of didactics of science with their own problems and scope. The word "own" is not being used in a selfish sense, or in on a whim, but it allows talking about peculiarities of an emerging field, which may achieve results than other disciplines cannot achieve in science teaching.

Consequently, it is important to think about specific didactics, taking care that not focus on teaching of contents for themselves, but, getting advantage from the ways, which scientific knowledge have been constructed, in order to form skills to overcome common sense, to enrich the natural way of reasoning, to teach reflect and interpret, or to solve problems, among others.

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