Investigações em Ensino de Ciências – V20(1), pp. 60-78, 2015

A LITERATURE REVIEW ON APPLIED PHYSICS IN MEDICINE IN THE CONTEXT OF TEACHING

Uma revisão da literatura sobre física aplicada à medicina no contexto do ensino

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Resumo

Este artigo é resultado de uma extensa revisão de literatura sobre física aplicada à medicina em 41 revistas CAPES Qualis A1, A2 e B1, 15 destas são brasileiras e 26 internacionais, entre os anos 2000 e 2012. Esta revisão mostrou que esta área de investigação é pouco explorada uma vez que apenas 51 artigos abordam este tema, 24 em periódicos brasileiros e 27 em periódicos internacionais. Nenhum deles usou enfoque epistemológico e apenas um estava embasado em uma teoria de aprendizagem. A maioria destes artigos (29) foram escritos por profissionais que não estavam relacionados à área da educação, o que pode explicar a falta de referenciais epistemológicos e teóricos. A física aplicada à medicina oferece um grande potencial para o ensino de conteúdos de física, pois situações relacionadas à saúde podem ser usadas para ajudar os alunos a dar mais significado para conceitos físicos. Assim, estudos adicionais com base em teorias de aprendizagem e visões epistemológicas da ciência são necessários e seu foco deve ser a investigação aplicada, de modo a envolver a produção de materiais potencialmente significativos para ajudar os alunos a alcançar a aprendizagem significativa em física.

Palavras-chave: ensino de Física; revisão de literatura; Física aplicada à Medicina.

Abstract

This paper derives from an extensive review of literature on physics applied to medicine in 41 journals CAPES Qualis A1, A2, and B1, 15 were Brazilian and 26 international ones, between the years 2000 to 2012. Such review showed that this research area is underexplored since only 51 papers approached this subject, 24 in Brazilian journals and 27 in international ones. None of them used an epistemological framework and only one was based on a learning theory. Most of these articles (29) were written by professionals that were not related to the education area, which might explain the observed lack of theoretical and epistemological frameworks. Physics applied to medicine offers a large potential for the teaching of physics since health situations might be used to help students add more meanings to physical concepts. Thus, additional studies based on learning theories and epistemological views of science are needed and their focus should be on applied research so as to involve the production of potentially meaningful materials to help students achieve meaningful learning in physics.

Keywords: physics teaching; review of literature; physics applied to medicine.

Introduction

Physics applied to Medical Science can be used to potentialize the occurrence of meaningful learning, both for the variety of phenomena it describes and previews and for its impressive effects of the use of modern technology, which can undoubtedly recommend the application of its study to diverse knowledge fields. However, this issue in relation to the teaching of physics applied to Medicine refers to the learning difficulties of its fundamental topics, as well as to the development of didactical strategies to facilitate the learning process that constitutes a relatively recent research topic in the area of science teaching. For this reason, we have considered relevant to carry out a review of literature on this subject that is the focus of this article.

It seems feasible, however, to emphasize that this subject has been, so far, not much investigated in the physics teaching area considering that, in the 41 journals comprised in this research, there were only 51 articles (24 in Brazilian journals and 27 in international ones) directed at such research issue, that is, physics applied to medicine.

It seems possible to say that such concern for physics applied to medicine appears to be the same over the thirteen years targeted here, since from 2000 to 2006 the sum of articles in Brazilian and international journals comes to 25 articles and in the last seven years the same number of articles (26) has been found.

This research involved the journals CAPES Qualis A and Qualis B, national and international, from 2000 to 2012. These journals are: Ciência e Educação; Physics Education; Science & Education; Science Education; Studies in History and Philosophy of Modern Physics; Enseñanza de las Ciencias; Revista Electrónica de Enseñanza de las Ciencias; Historical Studies in the Physical and Biological Sciences; Advances in Physiology Education; Revista Brasileira de Ensino de Física; Revista Brasileira de Ensino de Ciência e Tecnologia; Philosophy of Science; Annales de Didactique et de Sciences Cognitives; Caderno Brasileiro de Ensino de Física; Revista Electrónica de Investigación en Educación en Ciencias; Cadernos CEDES; Computers and Education; Investigações em Ensino de Ciências; Revista Eletrônica do Mestrado Profissional em Ensino de Ciências; Ensaio: Pesquisa em Educação em Ciências; Historical Studies in the Physical and Biological Sciences/ Historical Studies in the Natural Sciences; Revista de Enseñanza de la Física; Experiências em Ensino de Ciências; Cadernos de Pesquisa; Science, Technology and Society; International Journal of Science Education; Revista Brasileira de Pesquisa em Educação em Ciências; Scientiae Studia (USP); SEED Journal: Semiotics, Evolution, Energy, and Development; Science in Context; História, Ciências, Saúde-Manguinhos; The Physics Teacher; American Journal of Physics; Research in Science & Technological Education; Revista da Sociedade Brasileira de História da Ciência; Public Understanding of Science; Journal of Research in Science Teaching; Journal of Science Communication; Revista Eureka sobre Enseñanza y Divulgación de las Ciencias; Alambique (Barcelona); Revista Brasileira de Física Médica. In addition to the aforementioned periodicals, an article by Capelletto, Prestes and Santos (2008) presented at the XI Encontro de Pesquisa em Ensino de Física[1] was included, thus coming up to 52 articles. The journal and the number of article per each are listed in table 1.

Table 01 - journals research and articles found in every journal.

[1] XI Meeting of Research on the Teaching of Physics.

Journals Title	Articles found
Ciência e Educação	1
Physics Education	0
Science & Education	0
Science Education	0
Studies in History and Philosophy of Modern Physics	2
Enseñanza de las Ciencias	0
Revista Electrónica de Enseñanza de las Ciencias	2
Historical Studies in the Physical and Biological Sciences	0
Advances in Physiology Education	9
Revista Brasileira de Ensino de Física	5
Revista Brasileira de Ensino de Ciência e Tecnologia	0
Philosophy of Science	0
Annales de Didactique et de Sciences Cognitives	0
Caderno Brasileiro de Ensino de Física	1
Revista Electrónica de Investigación en Educación en Ciencias	0
Cadernos CEDES	0
Computers and Education	0
Investigações em Ensino de Ciências	1
Revista Eletrônica do Mestrado Profissional em Ensino de Ciências	0
Ensaio: Pesquisa em Educação em Ciências	0
Historical Studies in the Physical and Biological Sciences/ Historical Studies in the Natural Sciences	0
Revista de Enseñanza de la Física	0
Experiências em Ensino de Ciências	1
Cadernos de Pesquisa	0
Science, Technology and Society	0
International Journal of Science Education	0
Revista Brasileira de Pesquisa em Educação em Ciências	1
Scientiae Studia (USP)	1
SEED Journal: Semiotics, Evolution, Energy, and Development	0
Science in Context	4
História, Ciências, Saúde- Manguinhos	4
The Physics Teacher	5
American Journal of Physics	3
Research in Science & Technological Education	0
Revista da Sociedade Brasileira de História da Ciência	0
Public Understanding of Science	1
Journal of Research in Science Teaching	0
Journal of Science Communication	1
Revista Eureka sobre Enseñanza y Divulgación de las Ciencias	0
Alambique (Barcelona)	0
Revista Brasileira de Física Médica	9
Total	51

Methodology

Initially, there was a search in the previously mentioned periodicals for articles that had a connection with physics applied to medicine. Then it could be noticed that just one of those articles had a theoretical framework while all of them lacked an epistemological basis. Out of the totality of articles , there were just nine produced by professionals of the science teaching area, while the remaining ones came from the "hard sciences" area, what can somewhat justify this lack.

The next step was to categorize these articles in agreement with the parameters proposed by Greca and Moreira (2001) adapting them to the issue presented in this article because the categories proposed by those authors were applied to Quantum Mechanics. They divided the articles they had found into three groups that were adapted to fit the present article objective:

1) Students' conceptions about physics applied to medicine;
2) Appraisal/evaluation of introductory courses of physics applied to medicine;
3) New proposals of didactic strategies.

Articles categorized here complying with the first and second groups are scarce here. In the third group there were proposals for the inclusion of specific topics, shift of focus, curricular changes, and inclusion of new technologies (especially of computational resources). Such proposals, out of which only a few of them had actually been implemented and undergone evaluation, referred to contents taught at elementary, high school, and college teaching.

In this study articles were also categorized into five other sets:

1) Study of body fluids;
2) Radiations;
3) Historical approach;
4) Use of equipments that apply physics to medicine;
5) Influence of media.

The proposals of new didactic strategies were dealt with considering whether they had, or not, been implemented; they had, or not, undergone an evaluation process (qualitative, quantitative or data triangulation); the articles had, or not, a theoretical, experimental character, or both.

The organization of these articles into the groups proposed here, certainly, is just one way of categorizing them and, besides, some of the articles can be inserted into more than one category. It is necessary to point out that data presented here are those that the articles display, though some of them lack supplemental information to help the authors of this paper attain a more qualified analysis. It must be said that there has not been any reinterpretation of the students' conceptions about the physical concepts the articles' authors manifested in each article so that such concepts should correspond to their authors' own conceptualizations. It seems important to clarify at this point that carrying out a critical analysis of the literature reviewed here has not been part of this article objectives.

Findings

The corpus of this article comprises 52 articles, out of which 22 focus on teaching and 28 aim at scientific dissemination, and consequently they were not organized according to teaching level.

The authors, as we could identify them, are majorly 'hard science' researchers, while only a few carry out research on the teaching area. Just four articles in Brazilian journals and five in international ones were produced by teaching professionals. It might be for this reason that just one article presents a theoretical framework while not a single one has an epistemological background.

Only 11 of the international periodicals talk about the use of new technologies, whereas the Brazilian ones not even mention it. A feature to be stressed here is the focus on theory most of these articles have, since only 14 of them comprise experimental activities. There are 20 articles that refer to radiations, 10 to heart functioning and cardiovascular system, and five approach the functioning of the respiratory system.

Students' conceptions linked to physics applied to medicine

There are four articles in Brazilian journals and three in international ones that report research aiming at perceiving the students' prior conceptions about a given subject, The first one of them, "Ondas, Sonido y Audición: Ideas Previas de los Estudiantes en Ciências Médicas"[2], (Aiziczon , 2007) writes about the application of two questionnaires to medical students, in which the second one is more structured than the first one, and are directed at detecting what kinds of prior knowledge could hinder learning and what knowledge students already had could become subsumers to facilitate the learning of a given topic. Such findings were applied to develop activities that could improve the learning of physics in the health area by using the students' identified prior knowledge and their interests in such topics. Aiziczon (ibid.) evidenced the following alternative conceptions in those medical students:

- Not adequately discriminating between sound wave and acoustic perception;
- Getting confused about sound as a wave or physical phenomenon, and sound as hearing;
- Not differentiating wave from vibration, and vibration from sound;
- Inadequately relating intensity to pain and intensity with the human ear frequency.

In the article "O ensino de Física das radiações na formação de auxiliares de enfermagem e atendentes de consultórios odontológicos: sondagem de concepções sobre Raios-X com enfoque na prevenção e tecnologia" [3] (Costa and Costa, 2002), the authors applied a questionnaire that comprised six dissertative questions to the 39 students enrolled in a nursing aid course. Research findings showed that these students knew very little about radiation and that such a topic must be emphasized, especially the use of radiation and the ways to prevent accidents with health professionals.

The last Brazilian article in this category is "Concepções dos estudantes sobre radiações"[4], in which Capelletto, Prestes and Santos (2008) described a pilot investigation that looked for the ideas of 25 high school students about concepts they held on radiations before instruction, which they displayed in 15 dissertative answers to a questionnaire. Such answers showed that these students just had vague and unarticulated notions about radiations.

Bravo and Rocha (2008), in the article "Los modos de conocer de los alumnos acerca de la visión y el color: síntesis de resultados"[5], developed a six-year longitudinal study (three final grades of elementary school and three years of high school) focusing on studying what a group of students knew about vision and colors as they advanced in their schooling along elementary and high school. The authors then presented the students' predominant conceptions as they went on in their schooling. With this goal, they developed a qualitative study (case study), in which, before and after each intervention, a pretest and a posttest were applied, together with an additional posttest at the end of high school. These tests comprised dissertative questions whose answers were evaluated considering the variables light-object-visual system and interaction light-object, absorption, reflection, light-visual system, and perception. Afterwards, teachers divided these answers into four categories (clearly intuitive ideas, "correct" intuitive ideas though incomplete, and school science ideas). Authors concluded that, along the students' formation process, qualification and quantification of their given answers increased as they evolved from inductive to scientific ideas, although this transition did not reach total completion along the students' schooling period.

The article "The challenge of teaching introductory physics to premedical students" (Kortemeyer, 2007) proposed tests to a pre-med group of students that questioned to verify how

[2] Waves, sound, and hearing: prior ideas of students of Medical Sciences
[3] The teaching of physics radiations in the formation of nursing aids and attendants at dentist offices: probing on conceptions about X-Rays and focusing on prevention and technology.
[4] Students'conceptions about radiation.
[5] Ways of knowing what students know about vision and color: a synthesis of findings.

they are taught physics and whether they believe this discipline is important considering the objective of having a curriculum that privileges linking physics contents to their necessary applications in medicine. This research suggests that many students show interest in such things as medical images, examples of anatomy, blood flow but they do not perceive a connection between physics and medicine. Hence, the author suggests as a solution textbooks that establish linkages between these areas, as well as the use by the teacher of a more conceptual approach to this content area and the use of problem solving activities.

The last of the articles to approach students' alternative conceptions was "Challenges in teaching the mechanics of breathing to medical and graduate students", West, (2008), that comments on the difficulty and alternative conceptions medical students, as well as other undergraduates, have to understand the respiratory system, especially because it involves many concepts of physics. This article, however, does not present, or look for, alternative conceptions. It only mentions that its methodological proposal aims at easing up difficulties and alternative conceptions students might have about such contents even without identifying them.

Articles appraising introductory courses of physics applied to medicine

There are five articles involved in appraising introductory courses of physics applied to medicine, two in Brazilian periodicals and three in international ones.

Costa and Costa (2002) identify little knowledge about ionizing radiations and ways of avoiding accidents related to them at a nursing aid course. Authors attributed such deficiency to the way physics had been taught as, in general, either teachers did not cover such subjects or did not evince any linkage with medicine, that is, physics had been taught out of any context. Costa and Costa proposed this problem could be decreased with more contextualized classes and connecting it to medicine.

Toigo (2006) criticized physical education classes and suggested as fundamentally relevant to introduce theory to these classes because the student had to know how to avoid lesions and how to perform some movements so as to potentialize them. This topic could be useful to the development of an interdisciplinary work using movement as a means to add meanings to concepts of physics and biology. In her article, the author reported activities of biomechanics to be performed with students at initial grades of elementary school, in physical education classes when it is raining and schools do not have an indoor sports court. She mentioned two interventions in this situation: the first concerned charges/strains upon the body; the second focused on muscles and strength.

Duarte and Rezende (2008) criticized how the discipline Biomechanics was usually taught in the Physical Education course. This article was the only one to mention the use of a learning theory—Vygotsky's socio-interactions theory. According to the authors, students had difficulties in this discipline mostly because it involved concepts of physics. Generally speaking, teachers did not link physics to the human body; hence, they struggled to relate physics concepts in their application to the students' own bodies. Furthermore, physics classes dealt with much more theory than practice. These authors tried to ease up these problems by investigating how discursive interaction among undergraduate students of Physical Education had collaboratively interacted with the "Biomech" hypermedia system as well as how this interaction could be related to the internalization processes of concepts of Mechanics and Biomechanics.

Bravo and Rocha (2008) took a stand on the way contents related to vision and colors, which most teachers took for granted as topics students already knew, were taught at elementary and high school levels, as they also pointed out that teachers started dealing with such contents only at high school level, most of the time in a decontextualized way that became formalized after the

occurrence of contextualization and conceptualization. To reduce these hindrances, the authors followed a didactical proposal characterized by: 1) Presenting first those activities that allowed for starting the teaching and learning process by approaching daily phenomena that could be explained through the students' own ideas; 2) Complexity of the studied phenomena should be gradually increased; 3) Incorporating up to the end of instruction the problem-situations approach, which can enable students to deal with all variables and interactions proposed by science in order to explain the analyzed phenomena; 4) Presenting a content selection in agreement with the features of intuitive and scientific knowledge, curricular constraints, and the type of learning one is willing to potentialize; 5) Proposing an interrelated and recurrent approach to the contents(conceptual, procedural, and attitudinal) to allow students to interpret visual and color phenomena within daily situational contexts, as well as to use modeling and ways of doing and acting in increasingly more coherent ways with those proposed by science; 6) Sequencing contents so as to favor the development of explanations increasingly more complex, which implies dealing with a higher number of concepts and relations among them.

Kortemeyer (2007) pointed out the way physics applied to medicine had been taught without connection to context. Medical students were, thus, unable to perceive the relevance physics had in their future career considering it unnecessary part of their curriculum. The author drew these conclusions after he applied a questionnaire to those students. Based on their answers, he proposed teaching to be contextualized and related to medicine, less formal and more conceptualized by following the order of concepts listed in table 2.

Table 02 - content organization of physics applied to medicine as suggested by Kortemeyer (2007).

First Term	Second Term
Energy and Work	**Electrostatics, electric field**
Body scale	Equilibrium membrane
Momentum and collision	**Capacitors**
Relating to wounds	Defibrillator
Rotational kinematics rotational, rotational dynamics	**Current**
Muscles	Neurons
Temperature, solids, liquids, and gases	axon
Arterial plaque	**Magnetism; Induction**
Aneurism	Magnetocardiogram
Blood pressure	**Time variation current**
Bones and bone fracture	Cardiac pacemaker
Waves and sounds	Electrocardiogram
Ultrasound image	**Electromagnetic waves**
Human ear	**Mirrors and lenses; Optical instruments**
Shock waves external to the body	Human eye
Heat; thermodynamics	Corrective lenses
Metabolism	Eye laser surgery
	Endoscopy
	Interference and diffraction
	Limitation for medical images
	Quantum theory
	Fluoroscopy
	Electronic microscope
	Subatomic physics
	Magnetic Resonance Image Nuclear
	X- Ray images
	Radiotherapy
	Tracing isotopes

Studies with new didactical strategies

Out of the 54 analyzed articles, 20 proposed new didactical teaching strategies, and only five came from Brazilian periodicals. Thirteen of those 20 had been implemented and ten had been evaluated: three received both qualitative and quantitative evaluation, while the other seven underwent a qualitative analysis. The others were categorized as pertaining to articles stressing scientific dissemination. Following are presented articles proposing teaching didactical strategies, beginning with those that propose, implement, and qualitatively evaluate them.

Toigo (2006), as previously seen, after developing activities about biomechanics with elementary school students in their physical education classes, analyzed the students' comments, which, by the way, helped their own learning since they could put into practice the theoretical knowledge they had constructed.

Bravo and Rocha (2008) wrote their article based on a six-year longitudinal study (case study) with students enrolled in the three last years of elementary school and the three years of high school[6]. Their aim was to verify how students learn contents on vision and colors, and what ideas a group of students had about these topics as they progressed along their school years. The authors displayed the students' major conceptions in relation to such topics. They carried out a painstaking analysis of the students' answers in order to describe and characterize these students' ways of knowing. This evaluation was performed according to the variables (light-object-visual system) and interactions (light-object: absorption, reflection; light-visual system; perception) to which students had explicitly attended. The authors, based on these evaluation instances, made for each student a conceptual scheme to represent that shared explicative model. Since students did not use the same way of knowing to explain phenomena, the authors considered that the model had been shared when students applied it in 60% of the proposed problems. Characterization and exemplification of ways of knowing coherent with science were divided into four groups: clearly intuitive ideas; "correct" ideas though not complete, and school science ideas. Authors concluded that as students got a more formal education they abandoned their intuitive ideas in favor of those of school science.

Duarte and Rezende (2008) qualitatively analyzed the relevance of students' collaborative interaction with hypermedia biomechanical system (Biomech) and how this form of interaction could relate to the internalization of concepts of Mechanics and Biomechanics. Hence, 12 Physical Education undergraduate students (Baccalaureate and Licentiature) were randomly distributed into six pairs to work with hypermedia and their talks were taped and analyzed. Microgenetic analysis of the three episodes in which the pairs of students interacted with the "Biomech" suggested that action mediated by language had been determined by the support of semiotic resources (image, video, animation, texts and keywords) offered by the hypermedia system and by diverse sociocultural elements. They verified through the oral interactions between students and their navigation records in hypermedia that the collaborative interaction of those pairs could present structural differences, such as the classic pattern I-A-F (Introduction by the teacher, with a question for example; A- Answer by the student; F-Feedback offered by the teacher as a form of evaluation of the student's answer), "persuasive", and "internal" dialogues. Relations between individual-individual and individual-hypermedia, according to these authors, could favor internalization mechanisms. Findings suggested the importance of planning collaborative teaching situations that encourage social interactions by using cultural tools, such as hypermedia learning systems.

Swain (2000) employed a way of teaching the cardiovascular system using its analogy with the water distribution system in a city that made use of a tower in this process, in a medicine course.

[6] There are three years of high school in Brazil.

In such a system, water from a river or other source was pumped to the tower that had the function of adding to it enough pressure so that it could flow to the buildings' water tanks through a system of parallel pipes. Homeowners controlled its flow with faucets while pressure was maintained by monitoring the tower. In the analogy with the vascular system, the heart was the pump, aorta worked as the water tank, arteries did the parallel distribution through pipes, and arterioles were the faucets. Importance of baroreceptors control was also discussed as well as the role of the capacity of veins, muscles around the skeleton, dilation and contraction of blood vessels. The author' s analysis sought to find evidences for the benefits of this analogy in relation to whether understanding of the cardiovascular system had been subjective or based on oral reports and observation. He concluded that such analogy had helped the students' understanding of the cardiovascular system.

Next, there are articles that suggest teaching didactical strategies, implementing and evaluating them qualitatively.

Koehler, Martens and Pries (2007) based their article on an experimental activity in which they represented the human respiratory system, simulating pressure and volume changes in different ventilation forms. The lung volume changed together with pleural and internal lung pressure, which were monitored during a simulation of spontaneous breathing, forced exhaling, and mechanical ventilation to build a curve for the volume of air that had been breathed in and out as a result of pressure. 232 medical students, divided into 13 groups used that mechanical model in the discipline Physiology. The authors applied the following methodology: 1) Guided reading of a text on the respiratory system functioning; 2) Application of a pretest; 3) Students explained relations between pressure and volume at different moments of breathing; 4) Experimental activity was carried out to test the students' theoretical hypotheses; 5) Observation of the mechanical characteristics of the experiment and measuring of the pressure curve were discussed in group; 6) Posttest application. According to them, statistical findings provided evidences of a 70% improvement in the students' learning due to the experimental activity, though authors did not mention the type of statistical analysis they had used.

Anderson et. al. (2009) carried out an experimental activity to demonstrate the functioning of the respiratory system in human beings with the goal of replacing lab activities performed with animals, which started facing many ethical problems in addition to their high costs. Such activity comprised a digital blood pressure monitor and an integrated computer in real-time to show changes that resulted from the variations of pressure linked to the different stages of breathing. It was used to teach 427 college students, randomly divided into two groups (experimental and control groups), enrolled in the discipline Physiology. Afterwards, this experimental model was connected to a virtual data collecting system, the Biopac. Methodology comprised: 1) A pretest; 2) Reading about respiratory system functioning; 3) Experimental activity; 4) Posttest. The control group was not required to perform the experimental activity. However, pretest and posttest questions were the same for both groups and were handed out in class by the same teacher. ANOVA statistical test was applied to compare pretest and posttest answers of both groups. The statistical significance P value of this analysis was $<0,05$[7], which could be considered relevant. Such authors concluded that the use of such experimental activity had enhanced the students' learning of the following related physical content to the respiratory system: pressure, Bernoulli's equation, Boylle's Law. The authors emphasize that these results are from short, considering that the questionnaire was implemented right after the demonstration of the experimental activity and from the expository-dialogued class. He highlights that in future researches there is the necessity to apply the questionnaire after a while, aiming identify what was stored in the cognitive structure, that is, what has been send to the long term memory.

[7] It means that there is less than a 5% probability for these results not to be linked to the experimental activity.

Neto, Ostermann and Prado, 2011, aimed at teaching wave-particle duality in a technical course of radiology in which they applied a simulation of the Mach-Zehnder interferometer. Prior to the proposed implementation, the authors carried out an interview with students enrolled in different semesters of that course and also with former students in order to identify what kinds of knowledge those students had about physics in relation to what they had been taught along their course. Authors also interviewed teachers to get to know their expectations about what they expected students to learn along their classes and to acknowledge how important those studied contents had been in the teachers' opinion. Based on those two stages, the authors identified the need to reorganize the order of contents of the discipline Radiological Protection, emphasizing wave-particle duality as its core content and substantiating situations that were crucial to radiology technicians. Application of the materials they had produced happened in lecture classes, computational simulations performed in group, and discussions of the studied topics based on newspapers and/or texts available in the Internet. Performance evaluation of the carried out project was rooted on classroom observations and on the students' reports at the end of the term. Most students (81%) considered excellent the working methodology. The question, "Why do not many experienced technicians protect themselves?" , received by 72% of the students was answered that it was because the doses were quite small, while 16% of them said they did not know why, and 12% attributed it to the technicians' lack of danger awareness. After implementation, that picture changed because 69% of the students stated that experienced technicians did not protect themselves due to their lack of awareness, 13% said technicians forgot to do so, and 6% attributed this lack of protection to the technicians' haste to service patients.

Bastos and Mattos (2009) presented evidence that knowledge of physics could be used to help people live healthier lives according to Lawson's descriptive learning cycle and its stages (exploration, concept introduction, and concept application), in a medicine course. Findings suggested an appropriation of interdisciplinary knowledge to represent problems related to sound pollution.

Next, there will be a description of articles proposing teaching didactical strategies even though these had not been implemented or evaluated, therefore these articles have only description of a proposed teaching activity.

Uehara and Sakane (2002) proposed the use of the partial differential equation in the cardiovascular system to measure heartbeats and blood volume variation in different parts of that system. The authors suggest this propose be used to undergraduate physics students with no previous knowledge of human physiology.

Urhausen, Sperber and Kindermann (2004) expressed their concern with the teaching of circulatory system since it used many physical concepts. These authors describe techniques for measuring the time interval between successive heartbeats. This time series data can be used in undergraduate physics classes for instruction in resonance phenomena, scaling, and other methods of analysis including Fourier analysis and Poincaré plots.

Paul and Symes (2008) suggested the use of two activities that involve Ballistocardiography (graphic representations of a setback in the heart pumping action). Goodman (2001) showed thirteen different examples of exercises involving pressure-flow-resistance as well as the relation between concentration and blood flow. There were also some ideas for active learning and the use of straightforward illustrations related to kidney, respiratory, and cardiovascular systems adequate to Physiology students.

Carroll (2001) used examples already known by the students and utilized analogies to teach them pressure (P), blood flow (Q), and resistance (R) related to the cardiovascular system. Analogies were also used to teach Ohm's Law applied to cardiovascular systems. Equation Q= P gradient (ΔP)/R represented such law. One of these analogies referred to the river flow through the

middle of a *canyon*. The author pointed out to what happened everyday with each of the variables at each part of the *canyon*, then he applied that example to what happened in the cardiovascular system, and pointed out differences and similarities between those two systems. Moreover, he suggested that material to be used by students in a formal reading, afterwards they should get problems for which they would be granted enough time to think about those problems before proceeding to solve them. He suggested as well that video, and/or audio should be used with the illustrative materials to facilitate problem representations. The article is not focused on a specific course.

Kozlova, Chernysh and Matteys (2000) wrote their article based on an action research carried out in their classes in the course of Medicine related to the concepts of blood flow physiology. They proposed using mathematical models related to Poiseuille's Law, in its deferential form, to teach that topic. That mathematical model was applied to calculating distribution of hemodynamic parameters, estimating numerically the value for water amount between capillarity and tissue, and blood flow in the capillarity of vessels/veins. It was utilized by students enrolled in the courses of Biophysics, Physiology, and by physicists seeking specialization in this area. According to the authors, that model was effective in teaching blood flow physiology, though they did not present any reports concerning its classroom application and did not mention either quantitative or qualitative analysis that could justify such statement

Möllmann et. al. (2001), unlike others previously mentioned, did not emphasize either heart functioning and/or the cardiovascular system, in turn, they explored the most diverse activities to be performed stemming from an infrared radiation detector. They suggested activities for Mechanics, Acoustics, Thermodynamics, Electricity, Magnetism, and Optics in addition to their applications to technology.

Maclsaac and Hämäläinen (2002) recommended four situations in which a mobile/portable ultrasound device could be used in the classroom and at physics lab. The article is not focused on a specific course.

The following articles proposed teaching didactics and implemented such strategies, though they did not evaluate them. Anderson and Dicarlo (2000) developed a virtual experiment to teach about Electrocardiogram (ECG) and Middle Electrical Axis (MEA) seeking to replace activities with human beings for a better understanding of heart functioning since such activities provoked much ethical debate, besides being more expensive than software. The authors conformed to the following methodology: 1) Formal study of the topic through reading; 2) Teaching how the software worked; 3) Reduction and analysis of data; 4) MEA calculus and plotting; 5) Students had to answer questions related to ECG theory and practice. The authors displayed questions they had asked to other professionals.

The article by Pontiga and Gaytán (2005) sprang from the development of an experimental activity aimed at teaching students principles of hydrodynamics, more precisely Poiseuille's Law and Bernoulli's equation. Through such experimental activity students should notice the relation between pressure and blood flow to facilitate their comprehension of problems existing on this relation. It was a model for the circulatory system function linked to computer data capturing (Pico ADC-16) that utilized experimental activity data so as to compare them with its underlying theory.

The last articles on didactical proposals came from West (2008). He commented on the difficulties medical and undergraduate students had in understanding the respiratory system due to the great number of physical concepts it comprised. The author, seeking to diminish this problem, developed a set of materials he applied to undergraduate students taking physiology (however, he did not quantify such datum). He followed the following methodology: 1) Reading in three groups of about twelve students , in which each group had to read one of the assigned texts (the first was an introduction to the lungs' structure and function; the second was about ventilation; the third about

breathing mechanisms); 2) Students developed six experimental activities during two afternoons course meetings (three at each meeting); 3) Each student should solve a problem-situation that was then individually presented to the other groups. Those six experimental lab activities comprised: 1) spirometry (including flow curve related to volume); 2) measure of lung diffusion capacity in relation to carbon monoxide; 3) ventilation control; 4) exercise; 5) exhalation of different gases such as nitrogen; 6º) cardiac measurement of breathing.

Scientific dissemination

Twenty-eight articles were characterized as pertaining to scientific dissemination and were divided into three categories: 1) Essentially historical overview articles (18); 2) Those explaining the functioning of equipments used in physics applied to medicine (8); 3) Articles influenced by means of mass communication (2). Considering the 18 articles focusing on historical overviews, nine of them appeared in Brazilian periodicals and nine came from international ones.

Schickore (2000) emphasized the diversity of microscopic research in the 21st century. In the article there was an analysis of research carried out by two scientists, Ernest Wilhelm Brücke and Heirich Müller that investigated the retina structure and function. They did this by following different paths so that they presented different reports on this organ and its role in the vision process. Both used microscopic investigation and were concerned with the psychological interpretation their research might have had and the two of them used physics in the microscopic investigation they had carried out. Their approaches, however, differed in the way they had dealt with and treated the tissues, as well as in relation to the conceptual tools they applied to the data they had found. Such research indicated that the common trend of associating microscopic research to morphological studies of organic material had not been the most appropriate one to be carried out on such a topic.

Navarro et. al. (2008) showed the history of discovery of ionizing radiations, their biological side effects, and the need to control health risks involved in their use. They described the historic evolution of risk control for the use of radiodiagnostic in Brazil, demonstrating that riskiness did not reside only in the absorbed dosage, but also in diagnostic mistakes.

Almeida (2008) aimed at finding out the reasons that took Carlos Chagas Filho not to follow his father's steps (Medicine) at Manguinhos (a well-known research institution) but instead to study Biophysics and work at a university. According to the author, Carlos Chagas Filho's main contribution was the idea that universities were not just places of teaching but also of research for it was through research that a person could learn.

Ortega (2006) described the use of radiation equipments that allowed people to see them inside, which caused much issue when they appeared since such equipments would enable a person to observe images of his/her private parts. When X-Rays arrived, many myths came with them, such as that they were tools to spy on other people's lives, so that for many persons in those days such technology had to be banned. Today, some types of X-rays exams are used in the defense of criminals by presenting arguments that their brain anomalies are the real culprits for their criminal actions. Hence, according to the author, such technologies went further beyond the strictly scientific field as they entered cultural and juridical realms.

Tossato (2005), through the history of studies on the human eye, attempted at understanding developments of optical theories from ancient Greece to the end of the sixteenth century. Keppler started his research projects on this area in the seventeenth century, but his work was not included in Tossato's analysis because Keppler wanted to point out some relevant aspects of the human eye in its relation to philosophy, anatomy, and mathematics.

Borck (2001) sought to develop a historical description of the use of electricity to get a better understanding of brain functioning by relating electricity to mental life. This type of study opened the doors to public and scientific culture of electricity, as well as to physical processes during Weimar Germany period since, according to theory developed at that time, one could know people's personality traits just by reading the electric waves sent by the brain. Such idea spread throughout several vocational institutions and, afterwards, the electroencephalogram was adapted to be able to represent neuropsychological variations. Hence, that equipment broadened out its scope of use since it became not only important to determine personality (psychology) but also to understand mental processes (medical procedures).

Hyder (2001) presented a historical report based on readings of articles by Helmholtz, from 1860 to 1870, establishing a distinction between pure intuition and geometrical physics. Hyder also analyzed Helmholtz's works on geometry that were crucial to his developments in sensorial psychology, mostly those referring to the color continuum. Hyder (2001) pointed out Helmholtz's major contributions: 1) Color continuum property; 2) Distance and measurement influence; 3) Physical apparatus behavior when using geometry to carry out measurements. Helmholtz divided the theory of primary colors into three groups: physical; pigmentary; and physiological. Hyder suggested that Helmholtz had considered geometry a measuring tool and consequently the shape such system might have taken would depend on the context and on the physical environment experimental scientists had used.

Debru (2001) in his article focused on the history of Helmholtz's discovery, in the 1850s, of the speed of nervous impulse/momentum in frogs and of its consequences in human physiology. Helmholtz's conceptions of temporal space had applications both in psychology and physiology. Two main outcomes of those studies were his conclusions that neither environmental stimuli reached the brain simultaneously nor information sent by the brain could get immediately processed into actions.

Nye (2000) proceeded to summarize Linus Pauling's works because of his relevant contributions to biology, physics, and chemistry, which could describe him as an interdisciplinary researcher. An example of that was his discovery in quantum physics of energy resonance for which Pauling found much broader application in chemistry. Nye uses 89 bibliographic references, most of them papers written by Pauling himself.

Mosini (2000) centered on the history of resonance starting from the emergence of that theory with interpretations of Pauling and Wheland up to its modern application to medicine, more specifically in Nuclear Magnetic Resonance equipments.

Doménech and Navarro (2005) analyzed information available from the Spanish press in the period of 1943-1970 concerning medical equipments. According to the authors, the publications found in the periodic contributed to establish in Spain, an identity, reinforcing the self-sufficient, important information after the Spanish civil war. This is due to port war there were many pestilences, epidemics, so the means of communication showed investments on health area, helped the government to remain with in control. Netto (2009) presented a historical perspective of the Associação Brasileira de Física Médica (Brazilian Association of Medical Physics) and its contribution to the development of medical physics in Brazil.

Silva (2011) mentioned differences and similarities between medical physics in Brazil and in other countries, such as the United States and Germany, in which medical physicists were recognized as pivotal professionals quite differently from what occurs in Brazil. It was just recently, in 2011, that the medical physicist became a professional accredited with the International Professional Classification. The author also gave some details on the 18th edition of the *International Conference on Medical Physics* that first happened in Brazil in 2011.

Rodrigues et al. (2011) explained the program of Medical Residency at the Hospital das Clinicas, São Paulo, starting from the students' selection process to the end of the course. It stressed that the majority of graduating students (80%) worked in hospitals, 60% of them in São Paulo and 20% in the northeast area of the country, while the remaining 20% worked with corporations in the radiotherapy field in São Paulo and in some Northeastern states of Brazil.

Bernasiuk and Bacelar (2009) made a historical retrospective of the first undergraduate course of Medical Physics in Brazil, which in 1942 had its first graduating class at the Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS).

Brandan (2009) presented and overview of the medical physics area and stressed that in Latin America there was a lack of professionals in this field and that there should be an increase rate/factor of 2.4 to manage to meet the minimum needs of radiotherapy services. Ten percent of the medical physicists had a master's degree as the author also listed the requisites for the formation of clinical medical physicists to work at hospitals, calling attention to the fact that there was not much offer for specialization in that area and to the necessity of expanding the number of work places and vacancies.

Ratliff (2009) developed a guide for existing literature in medical physics in the field of radiotherapy. Gonçalves (2009), in turn, presented a historical overview of the Brazilian Nuclear Program and of medical physics in Brazil. He concluded that the expansion of the Brazilian Nuclear Program had not been accompanied by any increase in safety procedures, notwithstanding those benefits to medical physics had been brought through the BNP.

Considering the eight articles on equipment explanation used in physics applied to medicine, seven are in Brazilian periodicals and one is in an international one.

Machado, Pleitez and Tijero (2006) explained how antimatter could be applied to Positron Emission Tomography (PET); Carneiro et al. (2000) briefly described the development and applications of biomagnetism, which was a new interface between physics and medicine; Guimarães (2000) described some features of Nuclear Magnetic Resonance (NMR) and its relevance in the study of magnetic materials; Viscovini, Lopes and Pereira (2011) developed a graphic analysis software for radioprotection plans that calculated the values of external doses for radioactive equipments and indicated where it could offer danger to people; Bruno-Machado (2010) described the Neutron Capture Therapy (NCT)of the neutron by the boron using fundamental concepts of nuclear physics (fission and its products) in which a patient was injected boron containing 5 protons and 5 neutrons. Afterwards, a beam of neutrons irradiated him so that the atom of boron captured the neutron to become an unstable isotope, that is, radioactive. Such isotope was divided by nuclear fission into two particles, one was charged and had higher ionization power while the other was neutral but with enough recoil kinetic energy to ionize molecules at a distance equivalent to a cell diameter. Cancer cells absorbed boron and, hence, they were destructed. Conceição, Antoniassi and Poletti (2011) stated that each tissue type (normal, benign, and malignant) spread differently the incident X-Rays. Thus, those authors sought to identify mammary pathology by elastic spreading of X-Rays in human tissues. Souza, Sturzbecher and Felipe (2010) aimed at a new methodology for carrying out Functional Magnetic Resonance analysis to map active brain areas, which they called Entropy with Spectral Energy Density (ESED). Compared to other methods, ESED presented two advantages: 1) It was less affected by acquisition noises; 2) It did not need implementation or use of a referential theoretical function to represent stimulus.

Jesse (2008), in an international journal, reported an experiment he carried out in himself: he self-injected a cardiac marker, Cardiolite, to determine the time it took this substance to be eliminated from his body, using a Geiger-Muller counter to verify this time-span.

There were two articles that originated from research papers concerning media influence, one of them appeared in a Brazilian periodical and the other in an international one.

Chazan (2007) presented the findings of a research carried out in three different clinics that performed ultrasonographic exams so as to perceive medical and non-medical beliefs that existed in relation to such exam. Chew, Schmid and Gao (2006) researched the influence media had upon women about mammographic exams. The authors resorted to two different cancer institutes that showed them that the number of women who considered it an important procedure to be routinely done from the age of 40, and not 50, had increased with the dissemination of safety parameters for mammographic exams, though this statement lacked scientific support. To get to that conclusion these authors compared the materials on the mammography safety rules with women's perceptions about this issue, as well as they used those women's interviews with eight journalists working in health magazines emphasizing the relevant role of practice based on scientific knowledge.

Final Considerations/Concluding Remarks

It might be feasible to state that research on students' prior knowledge, though much developed in such areas as mechanics, thermodynamics, optics, or electromagnetism, appears to lack on articles about physics applied to medicine. However constant this interest might be, very little it has progressed along the years. Researchers outside the teaching area presented most of the articles studied here and this finding might serve as an explanation why those articles do not have either a theoretical and/or epistemological framework and, in addition, only a few are didactical proposals with a qualitative and/or quantitative evaluative analysis. Some articles aimed at reformulating the curricular grid in courses that sought an integration of physics and medicine, hence there seems to be a need of deepening this issue in further research proposals.

There are many articles that focus on historical contextualization, heart functioning, the respiratory system, and on radiations. Research articles on how medical equipments work are just a few and, because of its relevance in the contextualization of physical concepts by medical professionals, more research is urgent. Studies on the influence of media have had a small number of publications, thus, further projects on this area appear to be a must since this line of research comprises projects and studies on social representations (Hilger, 2009).

Methodology discussed in these articles was mainly qualitative and data triangulation was seldom used. It seems convenient to point out that the majority did not present a research method. Nearly all papers analyzed here had a theoretical approach that did not emphasize the application of new technologies.

The articles analyzed here suggest that students demonstrate difficulty in constructing knowledge of physics applied to medicine so that many attempts to do something to lessen this problem have been made, many of them using new technologies and experimental activities, though, without getting any successful and conclusive results.

This article intended to report what had already been done to integrate physics and medicine and to express future possibilities for studies on this relatively new field of physics.

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Recebido em: 22.04.2014
Aceito em: 30.06.2015