Modern Physics In Brazilian Secondary Schools[1]

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ABSTRACT

The current work reports a research that aimed to update the curriculum for the teaching of Physics. Topics from modern and contemporaneous theories are generally put aside in secondary school classes, for both course programs and formal university background designed to teachers of Physics focus on classic topics. We present the results of some researches that have been carried out on the introduction of modern topics in Physics classes that involved Brazilian secondary public schools and the University.

1 - INTRODUCTION

There has been a lot of talk about the need of innovation on the teaching of Physics at the secondary level[2], although little material presents clear, objective and practical proposals for teachers. Teachers usually have scarce (or no) time to dedicate study/research on teaching strategies that can prove to be effective in changing their traditional practices. Moreover, they face great difficulties to apply proposals that had been engendered within universities and research centers for the latter ones are distant from real classroom conditions. Consequently, educational innovations often remain away from schools and find no opportunity to be evaluated in practical situations.

The present article presents a teaching experience held by a research/intervention group that involved both University and secondary schools in Brazil. The group has professors and ongoing post-graduate students at the Education College in the University of Sao Paulo, and teachers from secondary public schools in Sao Paulo State, Brazil. Secondary teachers seemed to be dissatisfied with the teaching practices carried out during their courses: students with difficulties, students who could not understand the theoretical syllabi and who could not relate these with their routine lives, but only tried to go for a certain formula to solve proposed problems. Everyone seemed to search a way of reaching better results concerning student's acquisition. On the other hand, University researchers realized it was difficult to convert results of educational researching into effective innovations for the teaching of Physics in secondary schools.

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[1] This article will be published in the Proceedings of the International Conference on Physics Education, New Delhi, 2005.

[2] Brazilian school system comprises two cycles: elementary (1st to 8th grades, in two distinct cycles) and secondary (1st to 3rd grades). The latter would resemble the American standard High School system.

As a rule, research teams that investigate classroom facts tend to restrict secondary school teachers as mere appliers of proposals that have been carried out within universities. Secondary school teachers are generally "reproducers" of alien proposals to which little or no efficiency is credited and from which little understanding is reached. The current research team has university professors and secondary school teachers, and both sides share responsibilities in elaborating, applying and assessing the teaching proposal. "Fundação de Amparo à Pesquisa do Estado de São Paulo" (FAPESP)[3] provided financial support and necessary resources/conditions to the Physics teachers in the team. Such support was crucial for the successful teaching experience reported below.

The current research team had to face a challenge: to convey the **updating of part** of the Physics curriculum in secondary public schools in Sao Paulo State by introducing some of the topics of the Quantum Theory.

Curricular Updating

Physics is an experimental science and thus is in constant development. Last century, though, witnessed a greater amount of innovations and theoretical ruptures than any other historical period had seen. The range of knowledge within both microscopic and macroscopic perspectives in Physics has been enlarged as a consequence of disrupting classic concepts and meanings. Theories such as the General and Restrict Relativity and Quantum Mechanics have been used as ground for the production of knowledge in a new technical and scientific panorama.

These changes are not restricted, however, to the scientific community for their reflections are laid upon society as a whole. Examples may include new technologies that are present in day-by-day life. Nowadays, people listen to digitalized songs and work with computers based on semiconductors; public illumination includes photo sensors; medicine can count on magnetic resonance devices; nuclear plants have been growingly used in the production of energy in many countries; antique fossils and ceramic objects are dated through radioactive counters and laser has brought a revolution into surgical techniques. Even spontaneous phenomena, such as light originated in the Sun and stars, can be better understood with the perspective of the Contemporaneous and Modern Physics (CMF).

Science and technology widely modify our routine life and the distinction between natural and artificial is sometimes troublesome. The words *natural, nature* and *artificial* are frequently deployed in countless borderline phrases or expressions as

[3] FAPESP is the financial supporting agency that sponsored the current research.

“natural food”, “human nature”, “natural reaction”, “artificial tanning” and many others. We are led into deep thoughts when analyzing the meaning of such words: for instance, we tend to think whether we have really kept a distance from nature at a certain moment and now it is necessary to reestablish contact with it; whether there is any kind of food that is not natural; whether there is any difference at all between ultraviolet beams produced in a tanning chamber and the ones originated in the Sun. We tend to ponder why an orange juice is considered industrialized even though it is taken from natural fruit. The same thinking can be applied to a brick that is not conspicuously natural, though its raw material is clay! Humankind has introduced changes that modified not only nature but also its concept as men manipulate objects and living beings to survive.

The world as it is perceived today is significantly different from the world of some past decades because science and technology have modified the social environment. Thus, comprehending routine life without specialized knowledge is impossible. It is necessary to incorporate modern and scientific knowledge so that the world around us is fully understood.

Part of modern scientific knowledge can be found in general media. For instance, the spreading of scientists’ biographies, the communication of new theories, the presentation of curious facts/implications in programs/television channels such as the Discovery Channel, as well as through science magazines and journals such as *Scientific American*, *Science*, *Pour la Science* and so on*. Books (Alices Adventures in Wonderland*, *Mr Tompkins in Wonderland*, for example) aim to supply the public with specialized knowledge that has been carried out within science. The Internet is also a rewarding and widely growing means of spreading scientific information.

Contemporaneous and Modern Physics strongly penetrates our current society.

Students make part of such a routine that is modified by science and technology and take advantage of it as they face science names and figures that are brought in by media. Science fiction stimulates teenagers’ imagination – and also the ones’ who are not teenagers anymore – by inciting the search for new, virtual or extraordinary facts.

PAULO (1997) reports the influence of such scientific knowledge that is present in routine life by showing the existence of alternative conceptions on some subjects of Modern Physics on teenagers. The author claims that the production of such alternative conceptions originates from the interaction of the student with the science-modified world. Results like that have suggested that students with scientific knowledge obtained/built from routine life, where they behave as citizens, can be found in many classrooms. Physics teachers tend to find it difficult to deal with such students, for teachers have only classic knowledge at hand.

This scenario reinforces the need of a curricular updating that could handle with students who cannot recognize the meaning of the traditionally content taught at school in their lives. Therefore, the teaching of Physics at schools should be considered as a basic element for comprehension and action in the current world, for the understanding of the modern world and for the cultural satisfaction of today's citizens.

Schools in Brazil have not reached the point of appropriately handling with the knowledge originated in modern and contemporaneous theories. Traditionally, Physics in the Brazilian secondary school system has limited its access to theories from 17th-19th centuries. Summaries in didactic books or course programs approximately follow the historical development phases: students invariably start their studies with Kinematics (end of the 17th century), go on to Dynamics, Hydrostatics, Thermology (18th century) and reach Thermodynamics and Electromagnetism (19th century) only at the final steps. Such curricular organization reflects a hierarchical and linear conceptual structure that considers the historically "older" fact as pedagogically preliminary. The implication here is that students must go through the historical path of knowledge. Within such perspective, a person can only learn about the electromagnetic field (that is taught during the third year of secondary school) if he has already learned about Newtonian Laws (that are taught throughout the first year).

Such a way of considering the curriculum has prevented teaching from going beyond the borderline of the so-called classic theories (produced up to the 19th century), once the short three-year period at the secondary school is not sufficient to engulf the long scientific path of the physical science. The students' image of Physics does not match to its true scientific nature. School Physics, restricted to classic knowledge, kills the understanding of what is done today as research activities at university centers and laboratories.

Several Brazilian official documents show the need of an updating on Physics programs. The following paragraph can be found in the National Curricular Parameters (NCP):

> To the current merely propedeutic secondary level, scientific matters such as Physics have **omitted developments carried out throughout the 20th century** and presented traditional topics in an encyclopedic and excessively deductive manner. To the kind of education that is aimed at reaching, only a **permanent review** of what will be taught within each matter will grant **updating with the improvement of scientific knowledge**, and partly with its technologic incorporation. (page

8, bold types emphasized by authors. *NCP (2000) Secondary School*[4]

Such lack of tracking between school knowledge and wise knowledge has been pointed out in many researches on the teaching of Sciences.

Fourez (1994) seems to be concerned with political, social, economic and cultural factors that influence teaching, and the author considers the impact and the possible change of a kind of teaching of Sciences that would foment the Scientific and Technologic Literacy (STL) on students. He also emphasizes that the concept of Scientific Literacy as a guideline toward the teaching of Sciences is a consequence of what he calls 'crisis in the teaching of Sciences'[5].

The teaching of Physics based only on classic topics will not be able to develop the skills that are necessary for overall citizenship.

Brazilian researchers have tried to hold a deeper analysis on the difficulty of producing the curricular updating in Sciences. TERRAZAN (1994) analyzes the educational panorama[6] and focuses on the needs of inserting Modern Physics in secondary schools. He comes up with a pedagogical proposal guided by the image of knowledge as a three-dimensional, meaningful web that counteracts the current panorama, based upon a linear concept teaching and settled within an empirical view.

PEREIRA (1997) agrees on the fact that the contemporaneous world is highly technological and that its comprehension must come from schools, mainly from the programs within Natural and Social Sciences, Physics, Chemistry and Biology, so that relevant subjects can be included in the curriculum of an open minded citizen who understands the surrounding environment. A person who can make his own decisions and play his social and economic roles according to the current historical period.

VALADARES & MOREIRA (1998) defend the point that secondary school students should know the basics of today's technology, once it directly acts in their lives and can possibly define their professional future.

The scientific-technological dimension of modern society is not the only argumentative condition for discussing the introduction of CMF. The cultural dimension of Physics is also taken into account in such curricular updating, for the scientific

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[4] Part III, page 8.

[5] Two reports diagnose such crisis: the first, the UNESCO *Forum of the 2000+ project* (1993); the other, the 1980's-North American *Nation at Risk*. Such crisis has given room to attempts towards the renovation of the teaching of Sciences and its reconnection to the human context. Fourez identifies many axes in such movement: economic, political, social and humanly dealt values.

[6] Despite the changes that have occurred in the national education panorama since 1994, the focused topics in the present work have not been significantly changed to invalidate our review.

spreading has prompted the inclusion of scientific aspects as objects of the modern western culture.

Zanetic (1989) focuses on the importance of Physics in secondary schools:

> *the development of Physics is an integrating part of the social history, it is a social life product, for it brings in a huge range of factors and interests that are changing depending upon the time during which certain theories and concepts about the world had been developed.* [7]

The need to grant citizens domination on scientific-technological artifacts of routine life — material, cultural, concrete or virtual artifacts — leads to a curricular updating that could grant success to present topics within modern physical theories that had been developed throughout the 20th century.

"Thus, we can find many justifiable things in literature that allow us to set the following hypothesis: there is a national and international tendency to update the curricula in Physics and many substantiate arguments exist for that". (Ostermann and Moreira, 2001).

Researches on the TRANSPOSITION OF CMF INTO THE CLASSROOM

The need to introduce CMF into the teaching of Physics can be considered a consensual fact within the context of educational researches. However, the same cannot be said when teaching strategies are considered. The answer given to "Why?" is obsolete, but the answer given to "How?" is found in recent research.

Some researches have tried to evaluate teaching strategies on modern and contemporaneous contents within the Basic Education and preliminary results have been published.

Ostermann et al. (1999) describe the process of introducing and analyzing a contemporaneous physical topic – elementary particles and fundamental interactions – at a school in a southern city in Brazil, Porto Alegre. They describe the period through which the topic was applied at school and the obtained results, and finally they come to the conclusion that it is necessary to invest on **teachers' background**. COSTA & SANTOS (1999A) work on teachers' continuous background in a southwestern city in Brazil, Rio de Janeiro, and nearly come to the same results. They claim it is necessary to overcome both the lack of background held by teachers who are working at

[7] ZANETIC (1989), p. 22.

secondary schools and the scarcity of materials related to CMF. These authors suggest that teachers should exploit routine artifacts so that other themes such as laser, holograph, chaos and fractals, relativity and radiation could be developed *a posteriori*.

CAVALCANTI (1999) makes use of the media to present the theme Cosmic Beams through a historical approach on the evolution of ideas and experiments in Physics.

PINTO, A.C.e ZANETIC, J. (1999) studies the development of teaching materials related to Quantum Physics at the secondary level. He points out certain difficulties that appear when this topic is taught, such as the mathematical formalism, focuses on the need of a less formal and more qualitative teaching, and suggests that this could be "overcome" by making use of the History of Science. ARRUDA and VILLANI (1998) have developed a project that attempts to elaborate proposals of inserting CMF into the curriculum of Physics in Parana State, Brazil; such project involves professors of the Physics Department of a southern city university in Brazil, Londrina State University, and secondary school teachers.

Results that have been presented until now do not lead to an efficient teaching model that could transpose CMF topics into secondary schools, despite the fact that many researches have been published on the subject. According to Ostermann and Moreira, "...the number of published works that focus on the problem by considering the teaching point of view is still small, and even smaller is the number of those that have tried to place updating proposals in the classroom" (Ostermann and Moreira, 2001).

The lack of criteria to produce school knowledge in CMF topics can be pointed as one of the major factors that limit physical curricula to classic content. Zanetic's impending phrase, then, can be real: we should "teach the Physics of the 20th century before it is gone" (apud Terrazzan, 1992). The 20th century is gone and students are still forced to get along with the teaching of Physics that goes no further than the one from the 19th century.

Content selection and research teaching methodologies

The production of curricular innovations faces various obstacles. Broadly, such obstacles can be grouped into four categories: *definition and presentation means of the teachable content*; *teaching material to students*; *teacher's background;* and *infrastructure at schools*.

The most important obstacle is the first one, for the Physics courses held within Secondary Schools are generally very traditional and with few open doors for innovation. Topics have been placed in curricula and didactic books for several decades; teachers fully know the sequence of didactic activities and usually do not feel at home when changes are proposed. Facing the other obstacles mentioned above is a consequence of the latter. Most part of the teaching material that is available to students fits conditions found for the traditional teaching, where topics from the Classical Physics still predominate. Although Physics teachers keep a contact with the content of both Modern and Contemporary Physics, they feel comfortable teaching the very same Physics that they learned when they studied at High School. Thus, Classical Physics is seen as the "natural" content to be taught. Research data from years of experience on updating teacher's background education allows us to state that the **local/environment background** gained at schools is much deeper than the **formal** one undertaken at university centers.[8] Such fact gives ground to the definition of the third obstacle mentioned above *(teacher's background*), for it implements a true "didactic culture" change upon teachers. Infrastructure, as the last obstacle, seems to be a mandatory condition to any implementation that aims to innovate curricular topics in Physics, for schools are invariably adjusted only to the traditional teaching (such adjustment is not always enough, mainly in poor countries!).

The current research considered such obstacles and attempted to present solutions by building a research-action team consisting of university researchers, secondary level teachers and graduate/post-graduate students. The members of this group were transient along the two-year activity period but usually remained as follows: the team coordinator, who is a professor at the Education College and researcher on the teaching of Physics, six Physics teachers that work at secondary level public schools in Sao Paulo, one Master's degree student in the area of the teaching of Physics and one graduate student in Physics. To these permanent team members, temporary support people were added and they included researchers in Physics at the Physics Institute (University of Sao Paulo) and various graduate and post-graduate students.

Since the beginning, the internal team dynamics had been focused on the topic definition and classroom activity building with the objective of settling a teaching sequence that could allow secondary level students to reach both Modern and Contemporary theories. There is a great amount of topics that might potentially be taken into consideration when attempts to insert Contemporary & Modern Physics into the Basic School curricula are proposed. From Bohr's atom to the *Big Bang*, from time-space Relativity to the Chaos Theory, all of these are knowledge that was produced

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[8] See Carvalho, A. M. P., Garrido, E., Castro R.S. 1995, to obtain further information on environment background for Science teachers.

throughout the 20th century and in some way disrupts with the classic shapes of conceiving the physical world. The point is not that CMF as a whole should find room in secondary school curricula, for classic theories should certainly be an important part of it. The question is about the selection of topics that might be transposed, and such selection would be based, on one side, upon internal criteria to Physics itself as a scientific area, and on the other side, upon internal criteria to schools and their role in society.

We found a research in literature (OSTERMANN et al. 1998) on the selection of CMF subjects based on a survey with Brazilian professors and researchers in Physics. By making use of the Delphi approach, surveyed people were asked about which topics in contemporaneous Physics should be introduced into the secondary school curriculum. Suggested CMF topics were Quantum Mechanics (63%), Restrict Relativity (50%), Solid State (40%) and Particle Physics (38%).

This survey points out that the topics on quantum theory, as it seems natural, should be put in first place in the curricular updating of Physics for the secondary school. Lawrence (1996), Cuppari et al. (1997), Pinto and Zanetic (1999) describe indoor experiences toward the introduction of Quantum Mechanics topics in the secondary level. Greca, I. and Freire Jr., O. (2003) and Freire et al. (1995) discuss the introduction of this topic in the secondary school by approaching historical and epistemological aspects of the topic and its relations with learning-teaching processes. Such works emphasize difficulties in teaching the aspects of the quantum theory to young students. However, all authors show an optimistic view on successful possibilities.

The team members of the current research used the works mentioned above as discussion and study sources. The group assessed advantages and disadvantages of several themes related to the Quantum Theory, and these were taken into consideration when making the final decision about which attributes would be taken from the several themes of such theory: difficulties toward concepts; associated mathematical formalism; availability of teaching materials that are adapted to secondary schools; possibilities to make connections with classic topics that can be found in the traditional curriculum; possibilities to make connections with technology; possibilities to produce experimental activities. Within this context, the topic “duality between wave and particle” was chosen and seemed to fit all goals proposed by the research:

- It is placed halfway between Classic Physics and Modern Physics

- It sets the fundaments for the understanding of a series of physical phenomena (emission and absorption of radiation) and technological products (laser, photoelectric cells etc.)
- It favors model building on the microscopic world
- It opens possibilities for the understanding of some of CMF basic principles (energy quantization, exclusion principle etc.)

Physical topics related to this theme were:

1. spectrum lines
2. Bohr's atomic model
3. photoelectric effect
4. energy emission-absorption processes
5. Mach-Zender's experiment
6. Duality wave-particle
7. Possible interpretations on the Quantum Theory

The list of topics above comprehends a pilot course. Throughout a teaching year, the six Physics teachers were responsible for applying it in 12 classes of secondary level, sixth-semester students (above 17 years old).

The definite sequence was drawn in three years by considering the pilot course organization and application in previously chosen classes, analyzing the results grasped in classroom work and revising the activities built. Below is the sequence of the final topics:

TOPIC	
SUBTOPIC	**N# of Classes**
I. Models in routine life and Physics	2
II. Waves and particles	2
III. Introduction to magnetic and electric properties found in matter	4
IV. Short considerations on electric, magnetic and gravitational fields	5

V. Electromagnetic field and electrostatic induction	8
VI. Mechanic waves and light as an electromagnetic wave	10
VII. Light: color and vision	6
VIII. Spectroscopy	5
IX. Bohr´s atomic model	5
X. Photoelectric effect	3
XI. Wave-particle duality	3
Total	53

Teaching strategies were produced from former pedagogic experiences and developed by the same team in another project[9], and can be summarized as follows:

a) Historical and epistemological *Approach:*

b) *Use* of demonstration-investigation experiences[10]

c) Use of the *Open Laboratory*[11]

d) *Use* of open questions and problems[12]

e) *Use* of alternative bibliographical references for classroom *(Support texts):*

f) *Use* of videos*:*

g) *Use* of the Internet and software*:*

h) *Use* of analogies and metaphors[13]

Details on the sequence of classes and activities can be found in the Appendix.

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[9] A project that was formerly elaborated under the topic "Thermodynamics".

[10] these are **demonstrations** for they are conveyed by the teacher and observed by students, but are also **investigative** for they are not used to illustrate, but to make students think over a certain subject and over what he sees, and try to find explanations in the theoretical model. Alonso, Sanchez et al. 1992.

[11] this is a kind of laboratory in which students actively participate with teachers in every step, from hypothesis to conclusion elaboration.

[12] these are questions for group discussion, new situations are presented and the group of students can discuss and present their answers based on the explained theory.

[13] Metaphors and analogies are important resources for teaching, although questionable in scientific research, for they allow users to globally appreciate aspects that can be involved in commonly complex situations. By making use of functional and structural comparison, quite often it is possible to communicate ideas that could hardly be communicated with analytical resources.

Conclusion

The assessment of the strategies to overcome the pedagogical obstacles related to the inclusion of topics from both Contemporary and Modern Physics into the secondary school level curricula was possible because of the experience gained throughout the project. The results we obtained allow us to state that it is not impossible to have such topics taught to pre-university students, although epistemological, methodological and educational changes should occur. Our research did not lead to a more conclusive assessment on the level of learning that secondary school students have, for the primary objective focused on producing a didactic sequence that could be implemented within a real classroom situation. Limits and possibilities to update Physics topics within secondary level curricula could be defined as collaborative work was carried out by the team. We believe that the problem of updating and modernizing curricula can be worked on with the involvement of groups consisting of researchers in the teaching of Physics and secondary level teachers. Classrooms are complex environments with the influence of several factors. Considering such complexity on the whole should be the task of collaborative teams that would be able to bring out teaching proposals based upon problem analyses, solution proposals, tests and rebuilding procedures. This task might allow teaching to progress in such a way that it can follow the real background needs of today's citizens.

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Appendices

CLASSROOM TOPICS — SYNTHETIC CHART

Part I – Classical Physics: fields, waves and radiation

SUBTOPIC	CLASS TOPIC	ACTIVITIES
I. Models in routine life and Physics	1. Building a model for the black box	Students observe and manipulate a black box with an on-going transmission mechanism.
		Students should try to explain the working mechanism of the black box with a written text.
	2. The notion of a model	Reading out a text in class or in small groups.
		Answer written questions from the text.
		Question correction and end of discussion.
II. Waves and particles	1. Energy transmission through waves and particles	Students should work in groups and give the teacher a written proposal on how to turn a TV on by making use of the supplied material and considering the position pointed out by the teacher.
		Groups may test their own ideas and should try to go for the problem solution.
		Discussion on presented solutions.
	2. Topic systematization	Reading out a text in class or in small groups.
		Answer written questions from the text.
		Question correction and end of discussion
III. Introduction to magnetic and electric properties found in matter	1. Magnetic properties	Exploring supplied material.
		Exploring classroom materials.
		Classifying materials.
	2. Electric properties	The same as above.
		Table comparison.
	3. Discussion	Text dramatization.
		Systematization of ideas.
	4. Text continuation	Questions.
		Topic synthesis.
IV. Short considerat-ions on electric, magnetic and gravitational fields	1.Notion of field	Activity with a pendulum (Appendix IV.1).
	2.Electric, magnetic and gravitational fields	Field comparisons.
	3.Field representation	Investigative demonstration with magnet and iron dust. (Appendix IV.2)
	4.Continuation	Continuation.
	5.Closing	Questions and discussion.

SUBTOPIC	CLASS TOPIC	ACTIVITIES
V. Electro-magnetic field and electro-magnetic induction	1. Current generated magnetic field	Electric current.
		Investigative demonstration based on the classic Öersted´s experiment.
	2. Continuation	Students write an observation report.
	3. Concept sedimentation	Video clip from the film "Electromagnetism" (Ontario TV, Canada).
	4. Applying and extending studies	Questions on the video and text.
	5. Electromagnetic induction	Investigative demonstration based on the classic Faraday's experiment.
		Students write an observation report.
	6. Continuation	Questions on a Faraday's text.
	7 and 8. Applications of the electromagnetic induction (2 classes)	Engine and generator: students´ presentations.
VI – Electro-magnetic and mechanic waves Oscillatory phenomena	1. Nature	Activity with radio and mobile phones.
	2 and 3. Production and propagation of electromagnetic waves	Activity with computer simulations.
		Research on waves.
	4. Properties found in mechanic and electromagnetic waves	Activity with springs: Computer simulations.
	5 and 6. Exercises	Students work on exercises. Correction and systematization.
	7. Exploring oscillatory phenomena	Exploratory experiments.
	8. Understanding oscillatory phenomena	Theoretical and demonstrative class.
	9. Acceptance of the oscillatory model for light	Last discussions on the comprehension of light oscillatory phenomena and its acceptance history.
	10. Exercises	

SUBTOPIC	CLASS TOPIC	ACTIVITIES
VII Light: color and vision	1. Exploring color visualizing Comprehending color and vision mechanisms	Box with multi-color filters (Appendices VII.1 and VII.2).
	2 .Continuation	Activity discussion: what is color?
	3. Mixing light beams and pigments	Mix light beams in different colors and compare them with ink (pigments).
	4. What is color?	PowerPoint^{TM} presentation
	5. Closing and exercises	Questions (Appendix VII.2).
	6. Continuation	Correction and closing.

Part II – Modern Physics

SUBTOPIC	CLASS TOPIC	ACTIVITIES
VIII. Spectros-copy	1. Building a spectroscope	Spectroscope construction.
		Field research orientation.
	2. Observing lamps	Discussion on the spectra observed.
		Observations on spectra of a series of lamps.
	3. Writing a report	Continuation.
	4. Comprehending the basic operation of spectroscopes and different lamps	Explanatory class.
	5. Study of spectra and lamps.	Exercises.
IX. Bohr´s atomic model	1. Spectra types and spectral lines	Activity on spectra - Site da UFRGS – www.
	2. Atomic models	Explanatory class on Bohr´s model.

	3. Application of Bohr´s postulates	Explanatory class on Bohr´s postulates.
	4. Questions and exercises	Exercise solving.
X. The photo-electric effect	1. Light models and the photoelectric effects	Go back to the competition between corpuscular and oscillatory models.
		Work on the corpuscular model (particle).
		Video clip (Ontario TV, Canada).
		Discuss the photoelectric effect.
	2. Extending comprehension	Solve text questions.
	3. Going deeper into the comprehension	Use photoelectric effect simulations on various metals.
XI. Wave-particle duality	1. Analogy with the photon-personality	Present the analogy that will be carried out as a preparatory simulation to comprehend the experiment built for the definition of light nature (dialog between Newton and Huygens, book “Evolução da Física”).
		Students observe the photon-personality’s behavior and teacher gets to pick all hypotheses that may appear.
		Teacher goes back to observations, systematizes students´ hypotheses and prepares the analogy.
	2. Mach Zender´s Interferometer	Go back to the analogy presented with PowerPoint^{TM} in the former class. Present Mach Zender´s interferometer, experimental results (initial and to one photon), and results interpretation to determine light nature.
		Students watch the presentation and take part in the dialog carried out by teacher.
	3. Exercises	Present questions and hand support text out to students. Teacher should inform students that questions require opinions and that right or wrong answers respond to argumentation and not to a right absolute answer.
		Students answer questions individually and teacher assists them in the process.