Potentially meaningful teaching unit on Cosmology in the vision of the teacher of fundamental and average education

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Abstract. This research investigated the potentialities of the Meaningful Learning Theory (MLT) for the facilitation of the teaching of Modern and Contemporary Physics (MCP) content at the intermediate level. Privileging a qualitative approach, the work was based on the theoretical reference of the epistemology of teaching practice, on the teaching model of Gowin's theory and on the principles of Ausubel's Meaningful Learning theory for the elaboration of Potentially Meaningful Teaching Units. The entire study resulted in the elaboration of an Educational Product, constituted by the MLTs elaborated in the themes of Cosmology and Radioactivity. On-line questionnaires and interviews with physics teachers and activities used in MLTs were used as data collection instruments. Regarding the teaching of Cosmology and Radioactivity, the teachers suggested that they be taught through films, seminars and reading interdisciplinary texts. The analysis of answers by five teachers, regarding the efficiency and relevance of the strategy as a material to support the teaching in general, were positive. The teachers approved the potential of the material analyzed, activities, the instructions for execution, the time to plan and elaborate activities related to MCP, content not even emphasized in physics classes.

1. Introduction
Several studies [1-4] aimed at assisting teachers in the teaching of Modern and Contemporary Physics (MCP) through different approaches and strategies have been reported, such as: the history of science, experimentation and technologies. For example, [5] presented an approach for High School teachers, which includes a brief history of the development of topics of MCP like atoms, discoveries of the early twentieth century, conservation laws, fundamental interactions, standard model current, elementary particles, finalized with exercises and suggestions of activities.

The commitment of physics education researchers in developing approaches for effective teaching of MCP at the intermediate level, has been evident [1-5]. However, it was observed in an earlier research study [6] that investigated how physics teachers respond to the request of the official documents and the Secretariat of Education about the teaching of the contents of MCP in High School, that the physics taught in most institutions of this level of education is summarized in Classical Physics. Factors such as lack of confidence in teaching MCP due to lack of content knowledge point to the reality of inadequate training both in undergraduate courses and in continuing education opportunities for teachers.
From the perspective of training physics teachers, the National Professional Master's Degree in Physics Teaching (MNPEF) has as one of the objectives, "the improvement of the professional qualification of physics teachers in exercise in Basic Education aiming both at the performance of the teacher in the exercise of his profession as well as the development of techniques and products for the learning of Physics" [7].

New approaches to teaching have also emerged in an attempt to minimize teachers' difficulties and raise students' interest in the study of physics in general. Among them, we highlight the Potentially Meaningful Teaching Units (MLTs), didactic sequences elaborated based on David Ausubel's Theory of Meaningful Learning (MLT) [8], which have been shown to be efficient in the approach of the MCP at the intermediate level [9].

In view of this framework, the central question of the present research examines: To what extent did a didactic intervention on MCP subjects, through potentially meaningful teaching units (MLTs) have impact on the teaching of Physics at the intermediate level?

The above question is the basis for the hypothesis that the use of MLTs in the MCP study at the intermediate level could facilitate teacher education as well as help demystify the didactic thinking thought to approach the MCP at that level. In this sense, the research developed here favors teaching, teaching knowledge and teaching practice as punctuated by [10], emphasizing the epistemology of teaching practice "the study of the set of knowledge actually used by professionals in their daily work space to carry out all their MLTs " [10]. The overall objective is to investigate the potentialities of the MLTs for facilitating the teaching of MCP content at the intermediate level. More specifically, the objective was to elaborate an educational product made up of two MLTs to study the themes of Cosmology and Radioactivity and to analyze the results of the application of this product from the point of view of physics teachers.

In the composition of the MLT of Cosmology and Radioactivity it used different strategies such as texts, videos, experiments, computational simulations, conceptual maps, to assist the teacher in the exposition of the themes in the classroom. The educational product as a whole was thought and elaborated with a focus on the sharing of meanings, proposed in the triadic relation teacher-educational material-student of Gowin's Theory, which argues that in a teaching situation, the teacher, using educational materials of the curriculum, acts in an intentional way to change meanings of the student's experience [11].

2. Theoretical Framework
The present work is based on the Potentially Meaningful Teaching Units (MLT) and is also based on the perspective of the epistemology of teaching practice [10] and Gowin's model of teaching [11]. Proposition by [12], UEPS is a didactic sequence based on Meaningful Learning Theory (MLT) and elaborated with emphasis on the principles of progressive differentiation and integrative reconciliation. In this work two MLTs were developed and applied as didactic sequence of teaching. In general terms, a MLT is developed according to the steps proposed by [12]:

1. Create/propose teaching situations;
2. Propose problem situations, at a very introductory level;
3. New knowledge must be taught/learned taking into account progressive differentiation and integrative reconciliation;
4. With regard to the assessment of learning through the MLT, the author emphasizes the need to evaluate the student in a summative and formative way during all the stages of the didactic sequence, emphasizes the need for an individual summative evaluation after the sixth step and that the assessment of student performance in the MLT should be based, on an equal footing, in both formative assessment (situations, collaboratively resolved MLTs, teacher records) and summative assessment;
5. From the educational point of view, MLT will be considered successful if the assessment of student performance provides evidence of meaningful learning (meaning acquisition, understanding, ability to explain, applying knowledge to solve problem situations).

And as [2] predicts, knowledge does not happen at once; is progressive; therefore, the emphasis on evidence, not final behaviors.

In addition to knowing what is meaningful learning, the programmatic principles that facilitate such learning are also known, such as progressive differentiation, integrative reconciliation, sequential organization, and consolidation [3] some facilitating strategies, such as previous organizers, concept maps and V-diagrams [11].

These concepts were considered throughout the process of elaborating the MLTs of the present research, with the objective of constructing a potentially meaningful material that follows the principles of progressive differentiation - which recognizes the hierarchical nature of the dynamics of cognitive structure, retention and organization of the contents; and integrative reconciliation - which is the resumption of conceptual units in order to relate ideas, explaining similarities and differences between new information and subsumes, and can be facilitated if the teacher anticipates to the students general aspects of the contents to be worked on.

The studies developed by Maurice Tardif are aligned with the approach of this research, using the definition given by [10] of the epistemology of teaching practice as "the study of the knowledge that professionals actually use in their daily work space, performing their MLTs".

The objective is to understand how the teacher incorporates and modifies the knowledge used in the classroom according to the work context. It calls professional knowledge the set of knowledge transmitted by the institutions of teacher training, the disciplinary knowledge correspond to the various fields of knowledge, which in the case of this research is Physics, curricular knowledge correspond to the elements on which curricula are based (speeches, objectives, contents, methods), and the experiential knowledge is specific, developed by teachers and based on their daily work and knowledge of the environment. "They incorporate individual and collective experience in the form of habitus; know-how to do and know-how to be" [10].

From the point of view of the teacher-student relationship Gowin sees a triadic relationship between teacher, educational materials and apprentice, whose goal is the sharing of meanings [10]. Moreira [12] proposes that using educational materials from the curriculum, student and teacher seek meaning congruence.

In a teaching situation, the teacher acts intentionally to change meanings of the student's experience. The goal is to share meanings. It is a process that continues until the meanings of the curriculum's educational materials that the student captures are those the teacher wants them to have. At that moment, according to Gowin, an educational episode is completed [11].

3. Methodology
This study is carried out through qualitative research, aligned with the perspective of Moreira’s research [14], where he emphasizes that "one cannot fail to value the immersion of the researcher in the context, in interaction with the participants". Thus, "it is understandable that the focus of study will be progressively adjusted during the investigation and that the resulting data be predominantly descriptive" [14]. When searching for identification with such approaches, which also provides for the transformation of data and eventually the use of summaries, classifications and tables [15], the present research focused on the teachers' impressions regarding comprehension of the progressive, recursive and heuristic approach of the material elaborated for the teaching of MCP in the middle level.

The participants of the research were high school teachers (MS). Thus, five teachers participated in the investigation, all of them were members of the state education network, with some also teaching in the private network. Interviews with the five physics teachers were used as tools for data collection, elaboration and application of MLTs in high school classes, and application of a questionnaire for the evaluation of MLT by teachers.
From the answers given in the interviews it was possible to characterize the teachers who participated in the research.

a) Interview with physics teachers
In order to draw the profile of these teachers, an interview was carried out with the following objectives: To verify the professional trajectory, aspects of the university formation and the teaching performance; To investigate the occurrence or not of the teaching of Modern and Contemporary Physics (MCP), more specifically, the topics in the MLTs; Identify teaching strategies, ways of evaluating content; Identify the difficulties faced for teaching MCP.

From the theoretical basis of [10] we sought to identify aspects that demonstrate how the teacher incorporates and modifies the knowledge used in the classroom according to the work context, and which knowledge is built by the teachers when they introduce innovative methodologies in the classroom in this case, the use of MLTs in teaching MCP. For this, three categories of analysis were established: a) Professional and academic trajectory; b) Teaching of MCP; c) Difficulties faced.

b) MLT evaluation questionnaire applied to teachers
This questionnaire was applied to the teachers at the end of the interventions, through the MLTs conducted in the classroom. The objective was to evaluate if the teacher was able to understand the progressive, recursive and heuristic emphasis given to the activities proposed in the MLTs.

Compared with the assumptions of [10] and [11], teachers impressions were analyzed when assessing the potential of the proposal, giving suggestions and using it in their classes, as was the case with a teacher who participates in the search.

4. The Educational Product
The core of this study is the gathering of all the material produced during the research that will serve as a support to the teachers of Physics of High School. This study intends to show that the organization of available resources (texts, videos, simulations, experiments) through the MLTs can be a material of great potential to assist in the teaching of the MCP.

The elaborated MLT was applied during a two-year high school class at Campos dos Goytacazes/RJ, an institution in which the author of this study has been teaching the effective physics field since 2012. The topic of Cosmology is inserted in the first year curriculum of the MS being composed of a core of competences, skills and contents that students must develop and learn throughout the first grade, having in common the laws and principles that apply to the study of the Motion and Astronomy.

The competencies and abilities proposed by the Minimum Curriculum [16] that are present in the MLT-Cosmology are:
- compare the ideas of the geostatistical Universe of Aristotle-Ptolemy and Heliostatic of Copernicus-Galileo-Kepler;
- know the relations between the movements of the Earth, the Moon and the Sun for the description of astronomical phenomena (day/night duration, seasons of the year, phases of the moon, eclipses, tides, etc.);
- recognize orders of magnitude of astronomical measurements.

Understand the relativity of motion; understand the concepts of velocity and acceleration associated with the motion of the planets; present the modern cosmological models, especially the Big Bang theory as a sophisticated model for the evolution of the Universe.

The lessons related to MLTs included contents from the geocentric and heliocentric universe models to modern cosmological models, with emphasis on the Big Bang theory. Astronomical phenomena, order of magnitude of astronomical measurements, relativity of motion, velocity and acceleration concepts associated with the movement of planets and satellites, including Kepler's Laws and the Universal Gravitation Theory, were also studied.
5. Reports on the implementation of the MLT Cosmology

The proposed activities and the basic structure of the UEPS Cosmology are in Figure 1.

![Figure 1. Activity with students.](image)

*Initial Activities 1*

Initially the teacher explained to the students that she would be developing a research on Cosmology and that during the two months they would be doing activities on the subject. Next, the text was distributed with the case study:

Origin of the Universe (Appendix A) and together with the students, the teacher made the oral reading of the text. In the sequence, he asked the students to answer the questions present at the end of the text without the concern of answering correctly. At the end, they delivered the answers to the teacher. The group was then divided into five groups that received the following materials: cardboard box with holes in the sides of the edges, nylon wire, scissors and colored papers (Figure 2).

Students were asked to reproduce the Universe they imagined. They were free to make the stars and fix them in the positions they desired. At the end, each group briefly presented the constructed universe’s model. These activities were developed in two hours/class.

![Figure 2. Activity with students.](image)
Initial activities 2
The students were again divided into groups and given a kit (Figure 3). The teacher instructed the students that they should perform a simulation of the movements of the Earth, the Sun and the Moon and the consequences of these movements. Each group manually executed the simulation on the teacher. Then each group presented their simulation to the class. Both steps were recorded on video. This activity was performed in one hour/class.

![Figure 3. Activity with students.](image)

Initial problem situations
The students received a questionnaire with the initial problem situations. These questions should be discussed, answered and given to the teacher:

a) If the Sun is stopped, how do we see it perform a movement in the sky?
b) If there are other galaxies, are all of them centered on the Sun?
c) If the Universe has an end, what exists beyond this limit?
d) Are galaxies really moving away from each other, or is the space being stretched by cosmic expansion?

Then, the text “The Solar System” was given to students to read and write in groups, in groups, to prepare a theatrical text on one of the topics of Cosmology to be presented in the future class. This activity was carried out in two hours/class.

Introduction to fundamental concepts
Then the teacher presented as pseudo-organizer previous videos of the ABC series of Astronomy: Astronomy and Heliocentrism. Figures 4 and 5 bring the captured screens of the videos.

![Figure 4. Print screen of Astronomy video](image)

![Figure 5. Print screen of Heliocentrism video](image)
Following the teacher gave an expositive lecture with slide presentation approaching from the creation myths, through the geocentric and heliocentric models to the Big Bang. This activity was performed in one hour/class.

In the subsequent class, the teacher presented students with concepts of uniform circular motion, such as velocity, acceleration, and centripetal force from the motion of planets and satellites. And the law of universal gravitation and the laws of Kepler were presented. It was discussed the importance of the Order of greatness of the astronomical measures and some instruments that are used to realize such measures were shown. The students solved some exercises (Appendix B) about the concepts studied. Also discussed were the astronomical phenomena related to Earth and Moon movements, such as: day/night, seasons of the year, moon phases, eclipses/tides. The video Phases of the Moon, also of the series ABC of Astronomy is represented by Figure 6.

![Figure 6. Print screen of Moon Phases video.](image)

Then, the materials that the students used to simulate the movements of the Earth, Sun and Moon to verify the evolution of students’ learning about these movements were taken back. These activities were developed in six hours/class.

**Deepening knowledge**

By means of a presentation in Power Point the modern cosmological models were discussed, being retaken the Big Bang theory as a sophisticated model to explain the evolution of the Universe and the space-time theme addressing the theory of Relativity.

Through the reading and discussion of the text "A brief history of the universe", it was requested the elaboration of a conceptual map by the students with the concepts approached in the text. This activity was accomplished in 2 hours/class.

**Summative evaluation**

Students were informed in advance that there would be an individual assessment in order to allow them to show their understanding of the unit concepts. This evaluation (Appendix C) consisted of four, including objective questions in which they answered questions and performed calculations as well as subjective questions, asking the student to write a text about the Big Bang, and an issue in which they evaluated the strategies used during their MLT.

**Final class and evaluation of learning**

The students should present in this class the play they would prepare during the semester, but unfortunately they did not perform the activity, claiming that they could not organize themselves for
this. The issues of the case study and the initial problem situations were resumed. Some students have commented on the topic covered and highlighted the highlights for them.

**MLT Assessment**
To conclude, the teacher made a qualitative analysis looking for signs of Meaningful learning of the concepts of the unit, in function of the learning results obtained and the observations of the students. Such results will be better explained in a future paper.

6. Results Analysis

**Interview with teachers**
When analyzing the teachers' responses to the interview (Appendix D), some points that are in line with the researches of [10] stand out.

Regarding the professional trajectory, it is first verified that the average experience of teachers is approximately eight years and that previous professional activities had no influence on the choice of physics in the teaching activity, only one teacher had an affine activity to discipline - technician in electro technology. It is also important to note that the workload of Physics in the classes of the state public school in which they teach is reduced to only two hours per class, so these teachers have many classes to compose their workload, which makes it even teaching work.

As defined by [10], the epistemology of teaching practice studies the knowledge that teachers use in performing their MLTs in the school environment. Thus, it is understood that the teacher incorporates and modifies the knowledge used in the classroom according to the study context. In this sense, it is verified that the experiential knowledge incorporated "to individual and collective experience in the form of habitus and skills of know-how and know-how" [10] were acquired in the professional trajectory of teachers interviewed. These knowledges change, both through years of experience and teachers, as well as through the extensive workload fulfilled by them.

Other considerations also apply here to teaching work. [17] claim to be the teacher's routine with rules, which control the space and duration of activities. "It is a work whose development is scheduled in accordance with programs, assessments and, in a global sense, with the different patterns and mechanisms that guide the progress of students in the school system" [17]. Therefore, the teacher has to perform his functions considering rules pre-established by larger instances, often without his consent. The teacher, in this case has autonomy to decide the teaching methods, but the content to be constructed and the time available for it are predetermined. However, the authors see teaching as flexible work since "teaching, in a certain way, is always doing something different from what was prescribed by regulations, program, planning, lesson, etc." [17].

As for the university training of teachers, it was observed that all of them did a degree in Physics in public universities, which shows that they had a specific training in Physics and a recognized university. However, they pointed out flaws about the initial training they had. Professor D reports that the Physics course had a lot of appeal for mathematical formalism, and Professor E states that the classes were not geared towards teacher training.

Professor B also reports that his impression of the disciplines is that they are very technical, lacking didactic transposition for high school. In the conception of this teacher the course seems directed towards acting in Higher Education. It is evidenced in the teachers' responses that the disciplines of Classical Physics were privileged in relation to the workload and even with greater emphasis within the Physics courses.

These teachers' reports are in line with what [10] says about disciplinary knowledge, which correspond to the various fields of knowledge, which are incorporated into the training of teachers in the form of disciplines, during initial or continuing training. In the case of this research, in which the field of knowledge is Physics, it is verified that the disciplinary knowledge related to the MCP, originating from the initial formation of the teachers, were nicely when compared to Classical Physics.
Regarding the teaching of the MCP in high school by teachers, those who said they did not teach MCP pointed to factors such as: students' difficulties, reduced hours and the rarity with which these contents appear in the vestibular, not to do so. However, professors who have stated that they teach such content report the same difficulties they face when it comes to these subjects, but nonetheless they have been struggling to do so.

[10] states that throughout his careers, the teacher must also appropriate curricular knowledge, which corresponds to the elements on which the curricula (discourses, objectives, contents, methods) are based, from which the school institution categorizes and presents the social knowledge defined by it and selected as models of the erudite culture that teachers must learn to apply.

In this respect, [11] proposes that the curricular educational materials used by teacher and student should seek congruence of meanings. Thus, the teacher must act intentionally to change meanings of the student's experience. If the student manifests a willingness to learn, the teacher also acts intentionally to grasp the meaning of the educational materials.

However, if teachers do not fully incorporate disciplinary and curricular knowledge into their teaching practice, they will only be successful through continuous training that will bring the necessary training to practice their profession. It can be inferred, therefore, that due to the satisfactory training they had in relation to MCP, some teachers feel incapable to teach MCP contents.

Evaluation questionnaire
About the evaluation questionnaire of the proposal (Appendix D), the five teachers who participated in the initial research through the interview, received, via e-mail, the material consisting of the two UEPS and their respective annexes. In addition, they also received a questionnaire that was prepared for the teachers to carry out the evaluation of all the material gathered in the MLTs. However, at this stage of the research, only four teachers participated by submitting their assessments. The objective was to evaluate if the teacher was able to understand the progressive, recursive and heuristic emphasis given to the activities proposed in the MLTs.

Compared with the assumptions of [10, 17] and Gowin's theory [11], teachers' impressions were analyzed when assessing the potential of the proposal, giving suggestions and using it in their classes, as was the case with a teacher who participates in the search.

In order to do so, it was initially sought to verify how teachers have considered the principles of MLT in their classes, obtaining the answer that about 50% of teachers believe to take into account principles such as prior knowledge, use of previous organizers, the emphasis on progressive differentiation and integrative reconciliation. Thus, it is believed that the participants of the research were aligned with the ideas of this theory, which affirms that previous knowledge is isolated, the variable that most influences learning and that to promote meaningful learning it is necessary to verify this previous knowledge and teach wake up [18].

On the other hand, the programmatic principles and strategies that facilitate such learning, such as progressive differentiation, integrative reconciliation, and previous organizers [13], affirm that they are more subtly present in class planning of teachers.

This questionnaire was also asked to know the teachers' opinion about what would be a potentially meaningful material for them. The responses of the respondents were transcribed below:

Teacher A: They are materials that have a clear language regarding the physical concepts so that the student is able to interpret and relate to his daily life information about a certain subject.

Teacher B: A potentially meaningful material is one that engages the student's interest, which 'holds their attention' in the classes and activities carried out. In general, a material that takes students from the daily routine they are subjected to quite often: brush and painting, use of textbooks, lists of exercises, tests, tests, etc. Examples of potentially meaningful materials: materials that are capable of outsourcing student creativity and especially materials related to technology: interesting and modern videos, computer simulations, use of a cellular device as a pedagogical resource, etc.
Teacher C: A material that has meaningful potential for student learning, valuing students’ prior knowledge and allowing the student to relate the new concepts to what he or she knows.

Teacher D: potentially meaningful material would be any didactic sequence that promotes effective student learning, where the content is conceptually accessible and coherent.

The answers showed that teachers consider a material that is potentially meaningful, one that brings clear, accessible language related to the students’ daily life and that leads the student to relate the new concepts to what he knows. [19] points out that a potentially meaningful material is one that follows the principles of progressive differentiation, taking into account the hierarchical nature of the dynamics of cognitive structure and integrative reconciliation that is the resumption of content in order to relate ideas, explaining similarities and differences between the new information and the subsumers. Thus, meaningful learning can be facilitated if the teacher anticipates to the student’s general aspects of the contents to be worked on.

In this aspect, Gowin's teaching model [11], which proposes that in a teaching situation, the teacher acts intentionally to change meanings of the student's experience with the goal of sharing meanings. The importance given by Gowin to the educational materials indicates the relevance that should be given to the support material that teachers use in the performance of the teaching function aiming at the meaningful learning of the students. For this reason, it is believed that this material can be considered potentially meaningful.

As all participants in the survey taught or taught in the state education network, the feasibility of implementing this material in state public schools was investigated. Teachers revealed some drawbacks in the teaching of these subjects until then, such as: the training of physics teachers is not always adequate for the teaching of such contents, the physical and technological structure of the public school and the textbooks adopted by schools that do not always bring the contents in the sequence proposed by the minimum curriculum. However, they recognize that the activities elaborated in the MLTs can be easily applied because they are a complete planning that indicates how to apply them, besides bringing a diversity of activities contextualized making the education more pleasant and attracting the attention of the student. The answer from Teacher B presents in a very complete way what was exposed by the others.

Teacher B: I believe that the proposed MLTs meet the reality of the state education network. The subjects of the MLTs are not easily found in textbooks adopted by schools, and in other cases, the book presents content in a different volume than what is suggested by the state of Rio de Janeiro, for example, the theme Radioactivity/Nuclear Physics is content of the second year of high school in the state network, and presented in the book of the third year for the most part. In addition, they are subjects that will hardly be effective in learning if they are taught in a traditional way. Another relevance of the MLT is that the subject of Cosmology is the first content that students study in the discipline of Physics. Therefore, it is a way of making teaching more attractive and motivating for this student, who often comes to High School with a negative view about Physics.

Another important point is that the teacher who works in High School is not always prepared for the teaching of such content, because his/her training is limited only to a degree in physics (where the subject is not always addressed or in a way to be retransmitted for the 'language' of High School). And also, in the reality that we live in our state, teachers who teach Physics in some cases are licensed in Chemistry or Mathematics.

In the light of the teacher's point of view, it is concluded that the textbooks adopted by the schools do not present the contents of the MLT or diverge from the Minimum Curriculum regarding the series in which the contents were inserted. Therefore, the material produced in this research accomplishes its objective, in that it offers a material based on the competences and abilities of MP, which presents an innovative and attractive methodology for the student. In addition, the teacher of possession of this material, even if you have some limitations in your training regarding the subjects, will feel less insecure.

The questionnaire also sought the evaluation of the teachers about the approach of topics (Cosmology) treated in the MLTs. All participants considered the content approach to be positive, since
it is presented in a contextualized and diversified way. They also emphasized that differentiated activities attract the attention of the student and favor learning.

Regarding the strategies used, teachers emphasized the importance of bringing technology to teaching, such as videos, computer simulations and even slides, since technology is so present in students' daily lives. In the opinion of the teachers, the activities used in the MLTs are effective in the teaching of content, and consequently make learning more enjoyable.

The contributors

Teacher A: This material will certainly make a prominent difference in learning the study of cosmology and radioactivity not only for MS students, but for those who have not yet been able to learn meaningfully about the topics covered and how it is present in our lives. No doubt I would use this material when teaching classes in these subjects.

Teacher B: The material is a very useful tool for the teacher, for the practicality he generates for it. The teacher can have access at the beginning of the two-month period and have all the activities of the two-month period already done without the work and time spent researching and gathering material, and the material itself instructs the teacher in how to work the content.

Teacher C: As I mentioned the material is of excellent quality, and it brings proposals that really connect the daily life of the student with learning. The activities have the purpose that the students actually acquire the knowledge. In this material, the teacher is the mediator of the educational process and the student constructs its knowledge, fomenting and promoting the quality of diversified thinking.

Teacher D: The proposal of the material is very interesting, because it makes the student feel part of the process of knowledge acquisition. The diversity of strategies contributes to making the search for knowledge more attractive to the student.

The teachers' comments were positive, approving the potential of the material analyzed. Because it is complete, containing activities and instructions for execution, the material pleased the teachers a lot, since planning and elaboration of activities demand a lot of time.

It is important to point out that during the research the knowledge mobilized and constructed by the teachers can be identified. In reporting the initial training as physics teachers, the professional knowledge, those transmitted by the teacher training institutions, and the disciplinary knowledge, those specific to the physics discipline, focused on the MCP were evidenced. The experiential and curricular knowledge were shown in the reports of the teachers' visions about the experience in the school environment and about the identification they had with the curriculum and teaching methodology presented by the state education network and by the present research. The experiential and curricular knowledge of the teachers could be expanded and aligned with the scientific knowledge.

The importance given by [6] to educational material in the context of teaching is emphasized by [20, 15] in congruence with MLT, when he states that this should be potentially meaningful. This aspect of the theoretical reference used as the basis of the research and educational product is evidenced by the positive evaluation by the teachers of the material produced and the observations made by the researcher in the implementation of the MLT, giving credibility and confirming the feasibility of the evaluated material.

7. Conclusions

The teaching of MCP has been the object of several researches in order to investigate the difficulties encountered in this field of physics, such as the insecurity that the teachers have to teach these contents, due to the inadequate training in both undergraduate and graduate courses continued. However, in the perspective of training physics teachers, the MNPEF has been an opportunity for improvement in the qualification of teachers in the exercise of their profession, aiming the development of techniques and products for the learning of physics. In this sense, the work presented a proposal of differentiated
teaching with the use of MLTs, didactic sequences based on the Ausubel’s MLT [13], which resulted in an educational product.

In order to investigate the potentialities of the MLT to facilitate the teaching of MCP, the MLT-Cosmology was applied in a group of MS, whose activities were elaborated with a focus on the sharing of meanings, proposed in the triadic relation teacher-educational material-student of Theory of Gowin and the principles of the MLT.

In addition, an interview with five physics teachers, based on the epistemology of the teaching practice of [10, 17], traced the profile of these teachers who pointed out the difficulties of the students, the reduced workload and the rarity with which the contents of MCP appear in the vestibular, as factors to be faced in teaching these subjects.

The material produced was evaluated through a questionnaire applied to four of the teachers participating in the initial research, who considered the approach of the subjects attractive and motivating for the students and, for the teachers, a very useful tool, for the practicality that it generates by virtue of the same have access at the beginning of the semester to all the activities already done without the work and time spent in researching and gathering material, besides the material to instruct the teacher in the administration of the content. It should be emphasized that the activities developed in the MLTs have rescued the teacher's pleasure in to teach and the student to learn nicely. This statement can be made based on the comments made by the students, the interest shown by the majority of the students, their commitment to the activities, and the researcher's experience in the implementation of the MLTs.

Because of these facts, the material can be considered potentially Meaningful, as it demonstrated strong evidence of good receptivity of the students promoting a predisposition to learn the contents of Physics, a condition that favors meaningful learning, according to Ausubel [13].

Finally, it can be said that the results were encouraging and reinforce the hypothesis that the use of MLT in the MCP study at the secondary level facilitates the teaching of the teacher, as well as contributes to the student becoming an integral part of the acquisition process of knowledge, because the diversity of strategies contributes to make the search for knowledge more attractive to the student.

8. References

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Renato is a first year high school student at a state school, as do some colleagues, he believes that the discipline of physics is very difficult, and will probably be left low. The reason for this negative thinking, says Renato, is that Physics has many calculations and formulas that cannot be memorized. However, the physics teacher assured that in this semester will present a different proposal for the class, whose theme will be Cosmology and Movement.

"But what is Cosmology?" Is it the same as astronomy?

So began the questions of Renato.

- Cosmology is the science that studies the structure, evolution and composition of the universe, said the teacher, while Astronomy is the study of the stars.

- Funny! I thought that astronomy was referring to the signs of the horoscope, "added Renato.

"Not Renato, that's another thing: it's astrology!" Replied the teacher

"You're right, Teacher!" This subject is very interesting ... I was always curious to know more about it ... Renato thought.

- So let's start? You will answer some questions about the Universe.

The teacher concluded.

If you had in class, what opinion would you have about the issues below?

1) For you, how was the beginning of the Universe?

2) And how will the end be?

3) How is the Universe today compared to the beginning?

Appendix A

Case study: Origin of the Universe

Renato is a first year high school student at a state school, as do some colleagues, he believes that the discipline of physics is very difficult, and will probably be left low. The reason for this negative thinking, says Renato, is that Physics has many calculations and formulas that cannot be memorized. However, the physics teacher assured that in this semester will present a different proposal for the class, whose theme will be Cosmology and Movement.

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If you had in class, what opinion would you have about the issues below?

1) For you, how was the beginning of the Universe?

2) And how will the end be?

3) How is the Universe today compared to the beginning?
Appendix B

C. E. José do Patrocínio

Data: __/__/___

Aluno(a): _____________________  Turno: ______

LISTA DE EXERCÍCIOS DE FÍSICA

1. Marte tem dois satélites: Fobos, que se move em órbita circular de raio 10000 km e período 3.10^4 s, e Deimos, que tem órbita circular de raio 24000 km. Determine o período de Deimos.

2. A Terra descreve uma elipse em torno do Sol cuja área é A=6.98.10^{23} m². Qual é a área varrida pelo raio que liga a Terra ao Sol entre 0.0 h do dia 1º de abril até 24 h do dia 30 de abril do mesmo ano.

3. Na figura que representa esquematicamente o movimento de um planeta em torno do sol, a velocidade do planeta é maior em:

   a. A
   b. B
   c. C
   d. D
   e. E

4. Qual a intensidade do campo gravitacional da Terra sobre a Lua?

   Dados:
   \[ G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2} \]
   \[ M_{Terra} = 5.98 \times 10^{24} \text{ kg} \]
   \[ M_{Lua} = 7.36 \times 10^{22} \text{ kg} \]
   \[ R_{Terra-Lua} = 3.82 \times 10^8 \text{ m} \]

5. Um satélite é lançado horizontalmente em órbita circular à uma altura de 150 km da superfície da Terra. Adote o raio da Terra \( R = 6400 \text{ km} \), massa da Terra \( M = 6.0.10^{24} \text{ kg} \), a constante de gravitação \( G = 6.7.10^{11} \text{ Nm}^2/\text{kg}^2 \) e \( \pi = 3 \).
   a) Qual é a velocidade orbital do planeta?

   b) Qual é o período orbital?
Appendix C

1. A young country woman once decided to observe the sky. Every day she watched the sun set on the horizon. At first, she realized that the Sun was not setting exactly in the West, but a little closer to the side. After a year, she discovered that the Sun made a back and forth movement on the horizon, sometimes becoming more to the right and, at other times of the year, further to the left of the West. This movement observed by the young gives rise to what astronomical phenomenon?

2. Jupiter is the fifth nearest planet of the Sun, and the average distance between them is 7,78x1011 m. What is the order of magnitude of the distance between these two stars?

3. From the following questions, write a text describing the Big Bang theory. Use the back of the sheet to write it down.
   a) Did the Universe have a beginning or always existed?
   b) Which scientists participated in the discoveries related to the Big Bang?
   c) Does the Universe have a center?
   d) Is the Big Bang a blast? Why does the model have this name?
   e) The Big Bang is proven?

4. Evaluate your learning and physics classes since the Origin of the Universe case study.

Appendix D

Part I - ABOUT YOUR PROFESSIONAL CAREER

1. How long have you been teaching?
2. Before working as a teacher, have you ever had other professions? Which are?
3. Do you have another activity in parallel with the teaching profession? Which?
4. What is your teaching time, including the private network, if applicable?
5. What was the undergraduate course you did? Did you do any other higher education?
6. What is your impression of the subjects of physics you did at the university?
7. What was the emphasis of the disciplines of Physics: more for Classics or for Modern and Contemporary Physics (MCP)?
8. Can you identify any outstanding topics about MCP teaching at the undergraduate level? Which?

Part II - ABOUT MODERN AND CONTEMPORARY PHYSICS (MCP)

1. In your Physics class for high school, do you teach MCP topics? If so:
   What strategies do you use? History of Science? Experiments? Videos? Simulations? Others?
2. Have you discussed topics related to Radioactivity and Cosmology? If you have discussed, describe how the experiment was.
3. How do you usually evaluate content like the one above?
4. How do students handle when the subject is related to the MCP?
   Other observations
   If no: Why do not you teach?
   Other observations
5. What is your opinion about MCP teaching in the public school system?
   Positives
   Negatives
6. What is your opinion about the requirements for teaching MCP topics in high school?
   Positives
   Negatives
   Other comments
Appendix E

PROFESSIONAL NATIONAL MASTER IN PHYSICAL EDUCATION

Dear teacher

At this stage of our research, we have developed two Potentially Meaningful Teaching Units (MLTs) for the teaching of Cosmology and Radioactivity. Our intention is to encourage teachers to use them in their classes, but for this we need to listen to their considerations about the material produced.

For this, we count on your kind collaboration to analyze the material elaborated making its observations and criticisms with the purpose of verifying the acceptance of the same by the teachers.

Once again we thank you for your contribution.
1. In the elaboration of MLTs, the principles of Meaningful Learning Theory are used.
2. Check the option that best matches the principles you consider in your class.

Table. 1

| Principles                        | Never | Rarely | Sometimes | Often | Always |
|-----------------------------------|-------|--------|-----------|-------|--------|
| Previous knowledge of the student |       |        |           |       |        |
| Previous organizers               |       |        |           |       |        |
| Progressive differentiation       |       |        |           |       |        |
| Integrative Reconciliation        |       |        |           |       |        |

2. The relation teacher-student-educational material is of paramount importance for the capturing of meanings of the content by the student. For this, the educational material should be potentially meaningful. What does a potentially meaningful material mean to you?

3. With regard to the reality of the state public school, do you consider it possible to apply the MLTs in the high school classes in which you operate? Justify.

4. When it comes to the topics (Cosmology and Radioactivity), how do you evaluate the way of approaching these contents in the analyzed material?

5. What observations would you make about teaching strategies (videos, texts, experiments, computer simulations, conceptual map, etc.) used in the material?

6. In your opinion, can the activities developed in the MLTs encourage students to take an interest in Physics content? Justify.

7. As a teacher, what contribution and / or criticism would you make to this material?

8. Make a final comment about the material in question.