A proposal for a didactic sequence for the teaching of mobile cellular communications, integrating concepts of High School physics

https://doi.org/10.56238/sevened2024.009-031

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ABSTRACT

Developing and implementing didactic proposals to boost the High School Educational System are extremely important actions that can be carried out by the entire community. Thus, a Didactic Sequence based on the principles of Meaningful Learning was proposed, focusing on the teaching of the content of the Mobile Cellular System (Personal Mobile Service in the official definition of ANATEL), relating it to the content of Electromagnetic Waves of the discipline of Physics in High School. The Didactic Sequence, aligned with the official documents that guide Brazilian basic education, is an instructional resource for the contextualized teaching of the discipline of Physics and the purpose of its elaboration was to contribute in a participatory way to Brazilian High School. In addition, the Didactic Sequence was taught in High School classes at the Myriam Coeli State School, located in Natal-RN.

Keywords: Didactic Sequence, Mobile Cellular System, Physics, Middle school.

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INTRODUCTION

Surveys that prove the deficit in teaching-learning in schools, especially in disciplines involving calculus, as well as students entering STEM courses with deficits in physics and mathematics content, are themes widely studied in research and disseminated in the literature (TONIN, 2017). In this regard, it is essential that, in addition to testifying to these facts, there are initiatives to mitigate this problem. It should be considered that the contribution of the academic community in the educational formation of individuals, in order to minimize the difficulty that students have in the initial cycles of exact courses, can be initiated in the school phase, aiming that, by being present in the school life of the young person in high school, the academic community is able to corroborate so that the student has a greater preparation to continue in the engineering career, consolidating knowledge in a contextualized way (BARROS et al. 2012).

From this perspective, a Didactic Sequence (DS) was proposed, aimed at high school students, which was taught to a group of students from the public school system in the state of Rio Grande do Norte. And it was intended to exemplify how high school subjects can be passed on to students in a contextualized way with applicabilities seen in everyday life and studied in greater depth in higher education. For the construction of the Didactic Sequence, the theme of Cellular System in Telecommunications was chosen, since cellular mobile telephony is one of the fastest growing services in the world (Newton; Helou; Gualter, 2019) and young people are avid consumers of cell phones and the technologies associated with them (LIMA, 2006).

In addition, the theme is present in the Complementary Educational Guidelines to the National Curriculum Parameters (PCN+), in which the teaching of cellular telephony devices is suggested, describing antennas as good examples to explain the modulation, emission and reception of waves. In addition, the theme is also found in the Curricular Reference of Potiguar High School, document based on the Curricular Guidelines for Basic Education. The Referential presents the curricular matrix of the Physics component and among the skills expected of the student, it is to recognize wave phenomena, accompanied by the necessary conditions for their occurrence, and the objective of the knowledge of this aspect is the subject of Waves. Finally, the didactic suggestion presented by the document is the discussion about the Cellular System.

The document of the Curricular Guidelines for Basic Education reports that it is of paramount importance for educators to understand the proposals for structured themes, such as the one described, brought by the PCN+, assimilating them and creating consistent pedagogical projects, aligned with their educational institution, its circumstances and opportunities for implementation. Thus, the DS presented proposed a way of teaching physical principles, in a way associated with the Cellular System - which consists of Mobile Stations, Base Radio Stations and a Mobile Switching Center (RAPPAPORT, 2008) - seen in the Telecommunications Engineering course.

Knowing that the rise of science requires rules and methods that aim at new knowledge (MASSON, 2005), the elaboration of the written Didactic Sequence was based on Ausubel's Theory of Meaningful Learning, which is directed to learning in the classroom. To show how school learning occurs, Ausubel separated it into rote learning and meaningful learning (PELIZZARI *et al*, 2002). He defined that machine learning is stored in the human cognitive system in an arbitrary way, without attributing meaning. Meaningful learning, on the other hand, occurs when new information is linked to knowledge that the individual already had in his/her cognitive, thus managing to acquire meaning to the knowledge and build a conceptual hierarchy (MOREIRA, 1999). Thus, a meaningful way of learning was proposed, with content assimilation.

In this line of reasoning, the Theory of Meaningful Learning shows that the student must have in his cognitive structure some previous knowledge of a given subject so that he can anchor new related knowledge (SILVA; PÉREZ, 2018), thus, the study of the Mobile Cellular System is relevant, as it is part of the student's experience, being a tool for their communication, social interaction, and access to information (LIMA, 2006). In this sense, by recognizing and valuing the previous knowledge that students bring with them to school – which should not be underestimated, given their ease of access to information – students' interest in perceiving the importance and effectiveness of science in their daily lives is aroused (CELEDÔNIO, 2016).

Furthermore, another aspect brought up by Ausubel points out that the material used for the class must be potentially significant (MOREIRA, 1999), and must be applicable in the context of the student's life, providing examples, analogies, and illustrations (MOREIRA; MASINI, 2011). Thus, fundamentals of Physics were presented in a contextualized way with aspects of cell coverage, propagation and transmission/reception of signals. Using cell towers for example, Base Stations, antennas and transmission equipment that are geographically close to the student and/or that are part of their field of experience.

In this way, by using local examples, students are able to relate the concepts covered to their own reality and context in a more direct way (BRAZIL, 2006). This makes the content more meaningful and relevant to them, making it easier to understand. In addition, examples close to the students allow them to visualize in a concrete way how mobile communication technologies are present in their surroundings, strengthening the perception of the importance and impact of these technologies in their daily lives.

In addition, another proposed approach was to carry out a computer simulation, in which a feasibility study was carried out for a Point-to-point microwave radio link, within the city of Natal, through the use of the LINKPlanner software. The activity allowed students to understand in practice how transmission works in a wireless network, in addition to the analysis of the main parameters involved, such as signal strength, interference, transmission rate and distance between devices. In

this way, the intention was to provide an understanding Basic Operation of the Telecommunications System, its limitations, and possible solutions to ensure efficient communication. The simulation also provided the active participation of the students, contributing to the development of analytical and problem-solving skills, since it is a feasibility study.

Finally, it is emphasized that meaningful learning offers notable advantages, both in terms of enriching the student's cognitive organization and later recall and application in new learning experiences (PELIZZARI *et al*, 2002). Thus, the work was set out to develop a Didactic Sequence, based on Ausubel's Learning Theory, as a proposal for pedagogical enrichment in High School in the state of RN, and aimed to introduce students to other forms of knowledge that will subsequently be a contribution of experience to higher education.

DEVELOPMENT OF THE DIDACTIC SEQUENCE

There are a large number of paths that can be followed when developing a Didactic Sequence (DS), which vary according to the teaching objectives and characteristics of each institution. Therefore, it is up to the elaborator to select, prioritize and organize the specific path to be followed (BRASIL, 2006). The pedagogical project developed encompassed three main sections - defined in the **Table 01 -** which were the planning of the SD, the elaboration of the DS and the execution of the SD.

Table 01: Design of the procedures developed.

Sections	Procedures	What has been accomplished
I	Didactic Sequence Planning	▪ Definition of the topics taught in the field of Physics and their applicability. ▪ Definition of the pedagogical contribution used to enrich the teaching-learning process. ▪ Definition of the target audience to which the Didactic Sequence was taught.
II	Elaboration of the Didactic Sequence	▪ Elaboration of the visual presentation given to the students. ▪ Elaboration of the practical activity developed (feasibility study of point-to-point microwave radio link).
III	Execution of the Didactic Sequence	▪ Execution of the Didactic Sequence in the educational institution.

PLANNING OF THE DIDACTIC SEQUENCE

Topic taught

The PCN+ present six structured themes to assist the teaching of Physics, highlighting the importance of these themes for the organization of educational practice. For the elaboration of this Didactic Sequence, the theme proposed by the PCN+ called "Electrical Equipment and Telecommunications" was chosen. Within this theme, the thematic unit entitled "Senders and Receivers" was selected.

For the chosen thematic unit, the document states that today much of the information that circulates on the planet is through electromagnetic waves, so it is up to the student to understand the dynamics of how televisions and radios emit information. In addition, the document describes that antennas play a relevant role in explaining the process of modulation, transmission and reception of waves, as occurs in cell phone devices. Thus, in the planning of the DS, it was delimited that telecommunications subjects will be taught, with emphasis on the teaching of Electromagnetic Waves.

For the choice of the topic, it was also taken into account that the field of electromagnetism has a considerably abstract nature compared to mechanics, which can pose a challenge for students. This is because certain concepts, whether fundamental or more advanced, are not always properly understood due to the absence of models that can be easily related to their everyday experiences or previous knowledge (FERREIRA *et al*, 2019).

Pedagogical contribution

Moreover, in order for a transformation in the way the educational system works, it is essential not only to reformulate content, but also to rethink the methods used (PELIZZARI *et al*, 2002). Thus, the Theory of Meaningful Learning was articulated as a pedagogical contribution to the elaboration of DS, according to Ausubel. Considering that it is a Theory aimed at meaningful learning in the classroom (MOREIRA, 1999) and at school, the didactic relationship is established when there is a teaching project with the intention of learning (BRASIL, 2006).

David Ausubel's Theory of Meaningful Learning reports that meaningful learning occurs when new information is linked to knowledge that the individual already had in his or her cognitive, thus managing to acquire meaning to knowledge and build a conceptual hierarchy (MOREIRA, 1999). Thus, Meaningful Learning occurs from the connection between new information and previous knowledge, already existing in the individual's cognitive structure.

In this way, a pertinent pedagogical approach is created, since valuing the previous knowledge that students bring to school, in this case, knowledge about cell phones, allows capturing students' attention and concentrating efforts so that they recognize science as a relevant and effective branch of knowledge in their daily lives (CELEDÔNIO, 2016).

Alvo audience

The National Curriculum Guideline reports that considering the diverse and unequal reality of a large number of adolescents, young people and adults, Secondary Education must be committed to dealing with this situation, with the objective of seeking the transformation of the school,

recognizing that, although it is not capable of solving social inequalities by itself, it can contribute to social inclusion, providing access to science, technology and culture.

Subsequently, in order to ensure quality in the school, it is necessary that everyone involved in the educational process is committed, knowing that social responsibility is an educational principle (BRASIL, 2013). In addition, education is a right of young people guaranteed by the Federal Constitution of Brazil, and a duty not only of the State but also of society (UNICEF, 2021).

In this context, it is essential to develop pedagogical proposals that aim at the application of educational strategies to leverage high school education. Proposing, establishing, and progressively executing pedagogical projects allows not only to improve student learning in high school, but also fosters curricular diversity and establishes connections between theory and practice in the fields of science, work, and technology (BRASIL, 2016).

In this vein, this project was structured to be applied in high school classes, aligned with the physics subjects present in the National Curriculum Plan (PCN), which are part of the students' curricular structure.

ELABORATION OF THE DIDACTIC SEQUENCE

The elaboration of the Didactic Sequence was divided into two stages, namely, the elaboration of visual elements for the teaching of the classes and the example to be demonstrated of the feasibility study of point-to-point microwave radio link by means of software. **Table 02** will show that each activity is linked to the development of skills in the discipline of Physics, as established by the National Curriculum Parameters (PCN).

Table 02: Competencies to be developed by high school students through SD.

Activity performed by the student	Competence to be developed
Attend a class on Mobile Cellular Communications, with integration of Physical concepts.	Research and understanding: • To understand the Physics present in the world in which we live and in technological equipment (BRASIL, 2006).
Point-to-point link feasibility study.	Research and understanding: • Construct and analyze problem situations in physics and identify solutions (BRASIL, 2006). • Discovering the functioning of technological devices (BRASIL, 2006).

Presentation making

It is essential that the student perceives the meaning of Physics at the moment he is learning, and not at some later time, and it is crucial to achieve this goal, to take into account the students' experiential world, their close reality and the objects and phenomena with which they effectively deal (BRASIL, 2006).

Thus, in addition to bringing a theme that is present in the students' daily lives, the main examples of the Mobile Cellular System should be elaborated according to the geographic location of the school in which DS is being taught.

In addition, the slides should focus on a progressive construction of ideas of the topic addressed, starting from the basic principles of electricity and magnetism to the practical aspects of cell telephony, trying to bring the subject clearly and with plenty of visual elements. So that a potentially significant material would be produced.

Breakdown of activities

Next, the contents to be taught in the Didactic Sequence and the objectives linked to them will be listed in detail. As well as strategies on how to explore the themes during classes.

Content:

Introduction to Electricity and Magnetism:

- Benjamin Franklin and his contributions.
- A little history of Electromagnetism.

Objectives:

Understand fundamental concepts that have contributed to the understanding of electromagnetism.

Strategies:

The class should begin by explaining to the students that the subject of electromagnetic waves will be explored, highlighting how telecommunications use them to enable wireless communication. It should be explained, that the physical processes behind the connectivity of mobile devices and how the laws of physics play a crucial role in their functionality will be discussed.

It can be explained that several types of waves are part of our daily lives, such as the waves used in telecommunications (radio waves, television waves, and microwaves).

Therefore, tell the story of Benjamin Franklin and minister a little about the history of Electromagnetism and Electromagnetic Waves. Aiming for the student to make the connection of physics not only as an applied mathematics but also as part of history. Since, many times, the disciplinary contents presented in textbooks are so simplified that the student does not feel the need to ask where this knowledge came from (BRASIL, 2006). The idea is to pass on to the students that, in order for us to reach the stage of knowledge about telecommunications that we currently have, many thinkers made their contribution.

Thus, dedicating part of the class to discuss these scientists and their discoveries in an educational environment is an appropriate method to broaden the student's understanding of physical content and human aspects, in addition, this practice encourages the participation of students who have a greater affinity with the human sciences (FERREIRA *et al*, 2019).

Content:

Electromagnetic Waves:

- Fundamentals of electromagnetic waves.
- Frequency and Wavelength.

Objectives:

Introduction to the fundamentals of electromagnetic waves, including frequency and wavelength.

Strategies:

Explain to the student the explanation of electromagnetic waves. In which, the student must have the understanding that they are formed by two variable fields, one electric and the other magnetic, which propagate. And that this propagation can occur in a vacuum and in certain material media. In addition, explain the concept of frequency and wavelength, with the addition of talking about examples of electromagnetic waves, in which radio waves can be mentioned, including AM (Amplitude Modulation) and FM (Frequency Modulation), TV waves, microwaves, among others.

Questions that can be asked at this stage of the project, aiming at the participation of the students are "Why is it impossible for us to hear, here on Earth, a solar flare?" and/or "Why do we perceive the light of a lightning bolt before hearing the sound of it?"

Content:

Antennae:

- What is an antenna?
- Types of antennas and examples.

Objectives:

Introduction to antennas as essential components in the transmission of electromagnetic waves, as well as explain their operation.

Strategies:

In this part of the class, it should be exposed to the student that after the discovery of electromagnetic waves, electronic devices were created that were capable of emitting them in space, this device being called antennas. The student must understand the fundamentals that make the antennas able to transmit or receive information at well-defined frequencies. The presentation of how an antenna works is a key point in the presentation of DS, as students are users of electronic devices that need an antenna signal, but most do not know how they work in full (OLIVEIRA, 2018). It is important to know that antennas can be divided into different categories according to their applications and that their geometric shape is crucial for their operation.

In addition, antennas are good examples to explain the modulation, emission and reception of electromagnetic waves. A useful resource in explaining the concept of electromagnetic wave radiation is its analogy with soap bubbles, providing a clearer understanding for students. By comparing the propagation of an electromagnetic field, generating waves that close and radiate away from their sources, we can visualize this situation in a similar way to a soap bubble breaking off from a straw. As a sufficient amount of air is accumulated, the soap bubble grows in relation to the point of origin until it detaches (RIBEIRO; MARETTI; CARNIELLI, 2019).

Content:

Signal Transmission:

- FM Radio Broadcasting.
- TV station broadcasting.

Objectives:

Explore how signals are transmitted through electromagnetic waves, starting with radio and TV.

Strategies:

The purpose of this content is to explore how signals are transmitted through electromagnetic waves, bringing the example of radio and TV broadcasting. Through these examples, it is possible to work on different phenomena of physics that allow the waves to propagate through space and reach the receptors.

The point that can be worked on is the explanation that in order for these waves to be message carriers, they must be modulated, that is, they must undergo variations in their amplitudes (AM) or in their frequencies (FM). In which the difference between AM radio and FM radio can be explained to the student.

Other points that are important to work on in these slides is the conversion of the audio signal into an electrical signal. Explain that the audio signal is frequency modulated. And the frequency-modulated signal is then sent to the broadcaster's transmitter, where it is amplified. Making it clear to the student that this process is aligned with the fundamental laws of electromagnetic waves, which include straight-line propagation.

Continue the reasoning, showing that the transmitting antenna converts the electrical signal into electromagnetic waves, which are radiated into space, explaining to the student aspects such as the antenna that is designed to direct the signal in the desired direction, taking into account polarization and orientation, and mainly reinforcing the physical concept of radiation.

At all times in this process, mentions must be made to the field of physics, such as the explanation that electromagnetic waves propagate through space, undergoing reflections and diffractions. And that interference between waves can occur, affecting the quality of the received signal. Thus bringing in the physical concepts of reflection, diffraction and interference.

To conclude, the student may be asked if the waves captured by the receiving antenna should be converted into electrical signals, so that through the answers the doubts about the operation of the antennas are solved.

Content:

Cellular System:

- Introduction to the Cellular System.
- The three components of the Cellular System.
- Examples of Telecommunications Towers.

Objectives:

Introduction to the cellular system as a specific application of signal transmission.

Strategies:

In this content, the introduction is made to the cellular system as a specific application of signal transmission. It will be showing the student that the The main characteristic of mobile telephony is mobility, in which the user can establish telephone contacts even when moving. Showing that this is possible because communication is done without the use of wires, using electromagnetic waves. It is of fundamental importance to talk about the physical concept of the frequency used, to awaken the attention of the students that the telephone when it is within its coverage area is located even inside cars, such as inside clothes or inside our homes, showing that the wave in these cases is detected after undergoing reflections, refractions and diffractions. And that the

waves used in cellular telephony diffract very easily in small cracks, such as in the almost invisible holes in textile weaves (NEWTON; HELOU; GUALTER, 2019).

In addition, in this phase of DS, the student will be shown that the cellular system is formed by three components, making a brief explanation of each one of them. Explain the Mobile station, which is the cell phone itself, the base station, which is the antenna responsible for forwarding the calls, and the switching and control center, which is the brain of the system, responsible for managing calls and connecting to other base stations (NEWTON; HELOU; GUALTER, 2019).

Looking back on what has already been studied during this SD, the student may be asked the question "What are the main components of a mobile device (such as a smartphone) that make it a Mobile Station?", to form and reinforce points already worked on such as the antenna. Another question that can be asked is "What is the importance of mobility in a Mobile Station?". Leaving this moment so that students can participate in the class, with questions and answers.

tag. It is important to show the student examples of RBS concentration in the city in which he lives. This moment of the presentation should explain a little more about the RBS and bring questions such as "Why do you think that when walking on the streets we find so many antennas?". In addition, this part of the DS opens space for interesting discussions that can arouse the student's interest, such as 3G, 4G and 5G technology, the discussion on non-ionizing radiation, how the frequency band is regulated, discussion on the internet of things and satellite communication, among several other topics that can be incited by the teacher for the development of productive and enriching conversations of the student body.

Content:

Cell Structure:

- Cell and its importance.
- Base Station.

Objectives:

Explain the importance of the cell in cellular telephony, along with the Base Radio Station and comprehensive examples such as antennas in buildings.

Strategies:

In this part of the lesson, we will go into new details of the Cellular System, the first of which is the Cell. In which, it should be conveyed to the student that the coverage of each base station transmitter is limited to a small geographical area, called a cell, so that the same radio channels can be reused by another base station located at a certain distance (RAPPAPORT, 2008).

It is interesting to show the cell phone system as a whole, in a certain geographical delimitation. In which, students must be told that the geographic coverage of a cellular phone network is managed by several Base Radio Stations (RBS), which are installed in strategic locations to ensure the provision of services. And the geographic coverage strategy involves dividing the service area into cells, and each cell is serviced by an RBS.

The student should understand the main aspects of cell opening, such as the fact that the service area is divided into relatively small cells, to improve spectral efficiency and allow the reuse of frequencies in different cells, increasing the capacity of the network.

A very important point of physics that can be worked on at this point is power, in which the student can be reminded of the concept of power and talk about the transmission power of RBS and how they should be adjusted to ensure an effective range within each cell.

Finally, show an example of RBS close to the student, to reinforce past knowledge. The student may be asked, "We know that each cell is served by an RBS, but what equipment is part of an RBS?" After the answers given, a brief survey of the antennas and transmission and reception equipment can be made.

Content:

Mobile Telephony:

- Example of cell phone near students' school.
- Cellular antenna in the mall.
- Antennas on the façade of buildings.

Objectives:

Include practical examples close to the students' school to contextualize the concepts. And other examples with the antennas present in the mall.

Strategies:

Explain that RBS are installed in strategic locations such as towers, tall buildings, or elevated structures to ensure effective coverage. And that, careful network planning is carried out to optimize the arrangement of RBSs, taking into account factors such as population density, geographical features, buildings and natural obstacles.

Knowing that the student already has a good knowledge base of Mobile Cellular Telephony, it is essential Use local examples, so students can relate the concepts covered more directly to their own reality and context (BRAZIL, 2006).

One idea is to explore the geographical location of the students, presenting the school as a reference point for the example to be developed. Present the base stations that surround the students' school, showing in an illustrative way, the infrastructure behind the mobile communications they use in the school. Knowing that the role of contextualization in teaching is to present scientific knowledge so that, a posteriori, the student feels the need to insert it in his field of perception (BRASIL, 2006).

Thus, it is essential to present the RBS's, which are often imperceptible in the field of observation of students, despite being pillars that enable the connectivity of their cell phones. To illustrate this concept in a practical way, a simple example can be proposed, involving a RBS near the school. A suggested proposition to students is as follows: "Let's imagine that you are at school, concentrating on class, when suddenly your cell phone rings, and it is a call from your mother. What allows this call to happen involves the base stations close to the school. These stations act as messengers, transmitting your mother's voice to your cell phone and vice versa." Thus, the student can have the easy understanding of RBS's as invisible "messengers" that ensure that mobile communications happen efficiently, allowing them to receive important calls.

The physics behind mobile communication must be presented. Exploring that when the mother in the example spoke on the phone, her voice is converted into electrical signals, which are then transmitted as electromagnetic waves by the antennas of nearby base stations. Waves that travel through space, overcoming obstacles and traveling distances until they reach the antenna of the student's cell phone. I remind the student that, in the process of reception, the antenna of his cell phone converts these electromagnetic waves back into electrical signals, enabling him to hear his mother's voice.

Recapitulating, in this scene, fundamental concepts of High School Physics, such as frequency, propagation of electromagnetic waves, influence of distance on signal strength and absorption by obstacles present in the environment. Thus, students can connect a personal experience to the science that shapes the technological world.

Content:

Propagation of Signals:

- Reflection, refraction and scattering in mobile telephony.

Objectives:

Address the phenomena of reflection, refraction, and scattering that occur in the propagation of signals.

Strategies:

This part of the Didactic Sequence will reinforce to the student that when using the cell phone at school to send messages, make calls or simply surf the internet, one is using physics phenomena. In which, the properties of the waves involved in this process can be deepened. Concepts such as reflection, direction, diffraction and scattering are explored, all of which are essential to understanding how waves move and interact with the environment when they reach your cell phone.

It is also the purpose of this content to connect the context of Base Radio Stations (RBS) with the urban dynamics, using the specific example of the students' city. The idea is to show students that just as it happens geographically close to their school, there is also a mobile communication infrastructure in every city where they live, with strategically distributed RBS. Illustrative images should be shown, in which the presence of these RBS in the city can be highlighted, revealing how they form an intricate network to ensure efficient coverage.

By means of an illustrative drawing of cell coverage, the arrangements of RBS in cells should be discussed. In which, the student must have the knowledge that each RBS occupies a cell, with its overlapping coverage areas, forming a continuous mesh. And this arrangement of RBS in cells is crucial to optimize network capacity and ensure stable connectivity, allowing people to move between the entire city without losing signal.

Content:

Call Management:

- Mobile mobility.
- "Handoff" ("Handover").

Objectives:

Explore how mobility is managed on mobile, including Handoff.

Strategies:

This topic brings up aspects of cellular mobility, an essential feature of mobile communications. Understanding how it influences signal quality is crucial. The student should be shown that when moving with a cell phone, one is constantly moving in relation to the RBS and this generates a dynamic between the signal level and the distance from the cell phone to the tower.

In this part of the DS, the concept of power can be addressed. Showing that, the signal strength decreases as the distance between the cell phone and the tower increases. An easy-to-understand analogy to make is to compare this to a flashlight, saying that the farther away you are from the light source, the less intensely you will perceive it. Similarly, the farther away you are from

the tower's range, the lower the signal strength your cell phone receives. This phenomenon can be explored in the classroom, allowing students to understand the inverse relationship between signal strength and distance.

Here, too, the concept of handoff can be worked on, which allows a call to proceed without interruptions when the user moves from one cell to another (RAPPAPORT, 2008). And the concept of roaming, arousing the curiosity of students with the following question: "How do we receive calls when we change state?", knowing that to understand this process, it is crucial to understand how mobile communication networks collaborate to ensure a continuous experience, even when we are outside our area of origin.

It should be explained that when we change state and enter a new service area, outside the coverage of our home operator, roaming is triggered. In this scenario, the local operator temporarily takes over the management of our mobile device. In which can be mentioned the process of identification and registration of the mobile device, communication between operators, call redirection and mobility since, during roaming, the CCC also monitors the location of the mobile device and manages handovers between cells as necessary to maintain the continuity of communication.

Content:

Network Infrastructure:

- All Base Stations connected to a CCC.
- Interconnection of Telephony between different cities (Microwave Radio Links with Repeaters).
- Repeaters.

Objectives:

Explain how base stations are connected and the interconnection of telephony between different cities.

Strategies:

It should be noted that all RBS's in a mobile communication network are interconnected to a Switching and Control Center (CCC). And that, the CCC plays a central role in the coordination and efficient management of communication traffic. Functioning as the brain of the network, facilitating the exchange of information between RBS and mobile devices, as it manages resource allocation, device authentication, call and data routing, as well as monitoring signal quality.

In this part of the SD, two crucial elements in the mobile communications infrastructure will be addressed: repeaters and telephony interconnection.

It should be noted that repeaters play an essential role in expanding coverage and overcoming physical obstacles. Showing that they are strategically installed in elevated locations, such as towers, to receive and relay signals, increasing the effectiveness of mobile communication.

Knowing that repeaters play a vital role in overcoming rough terrain, tall buildings, and other barriers that could hinder signal quality, in this part of SD it can be talked about interference and different wavelengths. An interesting analogy is to compare this process to the echo of a voice on a mountain, where repeaters "reflect" the signal to ensure wider and more efficient coverage.

It is important to take care of the interconnection of telephony. The student is presented that this refers to the connection between different communication networks and this aspect is crucial to enable calls and data exchanges between different carriers and geographical regions. Teaching that by connecting the various parts of the telephone system, interconnection allows users to communicate without obstacles, regardless of the carrier of origin or geographic location.

Point-to-point microwave radio link design

Real-world problems tend to provide more creative solutions and are presumably more meaningful and stimulating than artificial problems (BRASIL, 2006). In this way, it is proposed that students do the feasibility study of a point-to-point microwave radio link between points, chosen by the students, in the city where the DS is being presented.

To do this, two specific software is used for this purpose, Google Earth and LINKPlanner. In this experiment, the following should be addressed: the geographic study via software for the allocation of RBS and possible repeaters, the importance of having a link with direct targeting and how some parameters, such as frequency range, tower height, antenna height, antenna gain, influence the link. The entire demonstration should be done by contextualizing the physical principles that govern the functioning described.

This phase of the teaching of the class has the direct participation of the students, in which they are encouraged to actively participate in the construction of the bond. Students are asked questions such as "Where do you believe is a suitable point to allocate an RBS?", "In an urban environment, what geographical barriers can be found so that the signal does not reach the receiving antenna? And in a rural setting?" What is the relationship between the frequency used and the distance of my link? Will any frequency be appropriate?"

Thus, by involving the student in challenges, estimating, quantifying or seeking solutions to real problems, it is intended to detach the paradigm that has been occurring in the teaching of

physics, by presenting physical knowledge only as a final result, leading students to conclude that there are no more relevant challenges to be solved (BRASIL, 2006).

EXECUTION OF THE DIDACTIC SEQUENCE

The proposed activities were developed in high school classes at the Myriam Coeli State School of Natal-RN, with two 3rd year classes and one 2nd year class, totaling 50 students who participated in the project.

The planned activities were developed in a time of 120 minutes. It takes 80 minutes to teach the dialogued class with presentations in the *data show* and 40 minutes to elaborate and discuss the radio link microwave point to point together with the students. Thus, the described time of 120 minutes for the application of the DS is composed of 2 classes of 40 minutes for the dialogued class with presentations in the *data show* and 1 class of 40 minutes for the elaboration of the radio link.

Figure 01 shows students from different shifts in the classroom watching the DS presentation.

Figure 01: Students attending an expository class on Mobile Cellular System.

In the initial minutes of the explanation, it was observed that the students did not formulate many questions and participated through stimuli by answering questions such as "Why in a storm, do we first see the light, and only then hear the sound of thunder?". However, the study of electromagnetic waves, initially with the absence of questions from the student body, took on a greater meaning when linked to the functioning of the cell phone, in which a greater participation of students interacting with the class through questions and answers was observed.

The above shows that it is of paramount importance that the learner demonstrates a willingness to establish relationships between the contents (MOREIRA, 1999), and that this disposition can be stimulated with the student's understanding of the relevance and applicability of knowledge (MOREIRA; MASINI, 2011).

As the presentation progressed, it was also observed a greater participation of the class with questions when the teaching of telephone call management began and the demonstration of examples

of Cellular Telephony that were geographically close to the school, which reinforced once again the idea that by using local examples, students are able to relate in a more direct way the concepts addressed with their own reality and context (BRASIL, 2006).

During the presentation, the students were shown that school subjects are the foundation of the functioning of what surrounds them. Since, many students who currently attend an educational institution unfortunately see knowledge as something distant from their reality, with little use or relevance for their daily needs (PELIZZARI et al, 2002).

In addition, after presenting local examples and demonstrations on how cellular mobile communication occurs, positive feedback was obtained from the students' participation. During the activities, in which they raised questions such as "How is an international call made?", "Can the cellular system affect our health with radiation?", and "What about the internet over Wi-Fi? How does it work?" Thus, the active interaction of the students and their thought-provoking questions demonstrated a significant engagement with the concepts presented, further enriching the learning experience.

In addition, it was noticed that during the exhibition of the radio link experiment, the constant interaction between theory and practice, through the construction of the link via software and stimulation of the active participation of the students were key elements throughout the exhibition, in which the students were enthusiastic, especially to choose the locations of allocation of the RBS's and the link parameters. such as tower height and antenna height, which contributed to the consolidation of the concepts presented. Reinforcing the educational principle that in order to assist and contribute to the construction of students' knowledge in school disciplines, the method of contextualizing the subjects that are seen in school and their applicability experienced by the student in the technological field is effective (BRASIL, 2006) and that in teaching, one must take into account the students' experiential world, their close reality and the objects and phenomena with which they effectively deal (BRASIL, 2006).

Finally, at the end of the lecture and radio link project stages, each student was given a sheet with six questions related to DS, so that the students' opinion about the DS taught could be surveyed. **Table 03** will present the first five questions asked, as well as the students' answers. It was reported that the student could answer the questions with "YES" or "NO".

Table 03: Questions asked to students at the end of the DS administration, with their respective answers.

Quiz Question:	Number of students who answered **YES** to the question:	Number of students who answered **NO** to the question:
Did the presentation contribute to increasing your interest in the discipline of physics?	42	8
Has the integration of physics concepts with the Cellular System made learning more interesting and motivating for you?	41	9
Do you feel that the class has broadened your view of the practical applications of physics in the real world?	48	2
Did participating in this project lead you to reflect on your career choice?	16	34
Do you believe that the experience gained from the project can be useful for your future academic or professional trajectory?	31	19

Something relevant, knowing that, in future moments, the school and the teacher assume a secondary role, and it is expected that the student will be able to establish learning relationships independently, with the knowledge acquired at school (BRASIL, 2016).

Overall, the positive impressions of the feedback indicate that the Didactic Sequence was well received, contributing to the students' understanding of the topic addressed.

RESULTS

The Law of Guidelines and Bases of National Education (LDB), highlights in item VIII of article 41, that it is the duty of Higher Education to exercise its function in promoting the democratization and improvement of basic education, through the implementation of extension programs that bring the two educational stages closer together. In this sense, the extension project entitled "A Contribution of Fundamentals of Telecommunications to Support the Learning of Physics in High School" was created by the Department of Communications Engineering of UFRN, with the aim of bringing together the spheres of Higher Education and Basic Education, meeting the established legal guidelines.

This Extension Project aims to work in high schools in order to contribute to the increase in the motivation of students for the study of Physics, exposing a direct connection between theory and practice, with the presentation of didactic material in schools.

Thus, the Didactic Sequence for the Teaching of Mobile Cellular Communications, integrating concepts of High School Physics, is a contribution of the Telecommunications Engineering Course to the Basic Education of the State, knowing that, by carrying out extension programs that integrate the knowledge and resources available in Higher Education with the specific needs and challenges of High School, It seeks not only to meet legal requirements, but also to strengthen collaborative ties between educational institutions.

But not only that, the project, in addition to providing benefits such as expanding access to educational resources, also gives students the opportunity to have contact with the academic community, which is of great importance, since, by being present in the school life of the young person in high school, the academic community is able to corroborate so that the student, consolidate knowledge in a contextualized way (BARROS et al. 2012), thus enriching the educational experience in the basic education phase.

CONCLUSION

Knowing that the lack of didactic materials is a common obstacle found in educational practice initiatives (BRASIL, 2006), the written Educational Product is a tool that tries to contribute to overcome this gap in Brazilian Basic Education. By offering a structured resource, being elaborated based on a research aligned with the official documents that guide Brazilian basic education and comprehensively addressing different concepts. In addition, its adaptability allows it to be used in different contexts and levels of education, promoting accessibility and the democratization of knowledge.

Furthermore, according to Ausubel, the material used for a class should be potentially significant (MOREIRA, 1999), and should have applicability in the context of the student's life, providing examples, analogies and illustrations (MOREIRA; MASINI, 2011). Which reinforces, once again, the importance of Educational Products like this produced. Since, when the disciplinary contents are presented only in textbooks, they are presented in such a simplified way that it seems to the student that it is only necessary to memorize the formulas and the main concepts (BRASIL, 2006) and if the student is restricted in memorizing formulas without understanding the basis of the theory, it will result in a fragmented and transient knowledge (ANTONOWISKI; ALENCAR; ROCHA, 2017), characterizing Mechanical Learning (MOREIRA, 1999).

Finally, it is stated that education in high school should provide young people with the opportunity to acquire knowledge that enables them to understand and explain physical phenomena (BRASIL, 2013), which was proposed by this work.

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