Modern Physics in Egineering Carrers

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Abstract: This paper shows an analysis of the materials and teaching strategies used in Physics I, II, III and IV within the Engineering courses in the National University of Comahue (Argentina).
The purpose of this research is to show that teaching strategies do not noticeably change, in spite of the progressive increase in the complexity and abstraction of the studied concept field, and the increasing tendency to solve Physics problems from a mathematical point of view. Besides, in the advanced Physics subjects, there are difficulties in putting the experiments into practice.
Classes are divided into lectures, problem solving and laboratory activities. The results of this investigation show that Physics I and IV theory lessons have the same methodological structure.
Class activities and problem-solving become Mathematics problems rather than Physics. They have statements with technical terms so as to be closer to Physics. In advanced Physics, there are no laboratory activities.
To sum up, may educational research results be ignored at university level? Should historical and epistemological aspects be taken into account while teaching Physics?
These and other questions make us think whether to continue with a rote learning or introduce some changes so as to achieve a meaningful learning.

Keywords: instruction, knowledge, intellectual integration, physics, ICCE2000

1. INTRODUCTION

In recent years, science teaching has been the subject of studies and research as regards the importance of historical, epistemological and methodological aspects, as a complement of their specific concepts. In general, this research has been conducted mostly with children and adolescents rather than higher education students.
Teaching scientific subjects to technical-course students is dramatically restricted to the acquisition of the correct factual knowledge, and the understanding of theories and laboratory techniques. Students are exposed to intensive lessons, extremely long syllabuses, long theory lessons and the solving of standardized exercises in order to successfully pass the subject.
This methodology rarely encourages students to reflect and develop meaningful learning strategies to acquire a complete and critical point of view of the science.
For a university teacher, teaching Physics means teaching concepts and techniques to reach the expected results. Laboratory experiments constitute the means to confirm what laws state, and repetitive exercises are "a necessary evil" to understand theoretical aspects.
In engineering education, it is supposed that, first, students have already learnt to deal with concepts in a cognitive way, so it is not necessary to train them; secondly, motivation is predetermined by the mere fact that they have freely chosen their course.
This paper addresses to the discussion of those assumptions that, among others, underlie the teaching of modern physics in our engineering courses, without taking into account the methodological approach that are more adequate for these complex subjects.

2. THEORETICAL FRAMEWORK

The complexity of educational practices, regardless the education level, leads to consider a series of interweaving factors, characterizing the activities carried out by both, teachers and students within the classroom. According to Doyle (1978; 1986), these practices have such features as multidimensionality (many events happen), simultaneity (many events happen at the same time), immediateness (many events happen rapidly), unpredictability (many unexpected and not planned events happen), publicity (everything done by teachers and students is public for the rest of the class), and historical (what happens is the result of what happened in previous lessons).

Therefore, there is no research paradigm, theory, model or program able to simultaneously deal with the complexity of the elements that characterize the educational practices (Shulman, 1989).
Classroom activities are, in part, the result of factors, processes and decisions originated in other areas such as the organization and functioning of the university system, the appraisal and prestige of certain competencies and knowledge, the curriculum and syllabus, the organization and communication among teachers, etc.
In other words, the classroom is not isolated and separated from its context. In order to understand what happens in it – the way teachers educate and students learn, what they learn, the ambiance of the class – further research would be necessary.
Basing our analysis on the teaching process and specially, on the teacher performance, we can consider two different points of view.
From a traditional outlook, teachers transmit knowledge and scientific principles. They are scientific storytellers, as J. Fletcher says, almost an animated text book. Students receive that knowledge, incorporate it into their vocabulary, and repeat "by heart" what teachers have said. Although it is not correct to refer to students as passive recipients – they cognitively work and elaborate in order to understand – they need some attention, practice and training to make progress in the subject.
New focuses on psychology and, specially on educational and instructional psychology adopt a different vision of the teaching and learning processes and conceive the role of teachers as advisers, guides and a help for students to build meanings with sense. From a constructive point of view, this process characterizes learning.
This educational help may adopt many different forms: it can be indirect or distant, such as how the teacher organizes and selects the settings and the teaching - learning activities (the use of classrooms, laboratories, libraries, the timetable, the social organization of students, etc.); or it can be direct, when there is teacher – student immediate and reciprocal interchange (Coll, 1999).
Our proposal is based on Ausubel-Novak-Gowin's theory. Some essential features of this theory, which form the central theoretical framework of this paper , must be introduced.
The key idea in Ausubel's theory is that of MEANINGFUL LEARNING, which he defines as "non-arbitrary, substantive, non-verbatim incorporation of knew knowledge into a person's cognitive structure" (Ausubel, 1968). This means that the learner must make a conscious effort to relate new knowledge to knowledge he/she already has. For example, a student learning new information on centripetal acceleration would consciously relate this knowledge to what he/she already knows about acceleration in general.
Meaningful learning involves the linkage of new information with a specific knowledge structure, which Ausubel defines as subsuming concepts or subsumers, existing in the individual's cognitive structure (framework of hierarchically organized concepts). In kinematics, for example, if the concepts of vector and scalar already exist in the learner's cognitive structure, they serve as subsumers for new information concerning a certain type of vector and scalar quantities, e.g., velocity and speed. Thus, during meaningful learning, new information is associated with existing relevant subsumers in cognitive structure. This association, in turn, results in further growth and modification of the existing subsumer. In our example, an intuitive idea of speed would serve as subsumer for new information concerning the motion of particles.
Ausubel uses the concept label SUBSUMPTION to represent the idiosyncratic nature of meaningful learning and the fact that new knowledge is usually incorporated (subsumed) into more general concepts. Each person's cognitive structure is unique, and hence subsumption of new knowledge produces a cognitive interaction product that is dependent both on what concepts the learner already has and the material presented.
Ausubel distinguishes between meaningful and rote learning. Rote learning occurs when relevant concepts or subsuming concepts do not exist in the individual's cognitive structure. In such a case, new information must be arbitrarily stored in the cognitive structure, that is, it is not linked with existing concepts. An obvious example of rote learning in kinematics, is the rote memorization of formulae. For example if the general ideas of acceleration and velocity were not available in the learner's cognitive structure, she/he could only rotely learn that acceleration is the rate of change in velocity and velocity is the rate change in position vector. She/he could memorize this, but it would not result in acquisition of meanings. According to Novak (1977), rote learning is always necessary when an individual acquires new information in a knowledge area completely unrelated to what he already knows.
Ausubel's theory has another two key learning principles: PROGRESSIVE DIFFERENTIATION and INTEGRATIVE RECONCILIATION.
According to the principle of PROGRESSIVE DIFFERENTIATION the most general and inclusive ideas of the discipline should be presented first, and, then, progressively differentiated in terms of detail and specificity. Following this principle, acceleration should be introduced, at the beginning of the explanation in order to serve as conceptual "anchorage" for subsequent presentation of the concepts related with motion. A traditional instruction should follow the content organization found in most textbooks on the subject, which starts with reference frame, distance, displacement, velocity and finally acceleration.
When two or more concepts are seen to relate to each other in a new way, perhaps to describe a new perceived regularity, INTEGRATIVE RECONCILIATION of concepts has occurred. This principle is also used in the organization of our

instructional model. According to that, for example, force and acceleration are not studied separately: they are related from the beginning. We think that this principle is really important in the learning of physics, because it is a discipline where the concepts are very interrelated with each other. So, we have organized the content of this unit in a sequence according to this principle (which is not necessarily the sequence found in most textbooks).

A classical sequence for an introductory course in kinematics at college level starts with reference frame and displacement, then it goes into velocity and speed and it ends with acceleration. The concept of displacement, which is a key concept but highly specific, is at the beginning of the sequence, and acceleration, which is the general concept describing kinematics phenomena, is at the end. In a sense, this sequence is exactly opposed to Ausubel's theory because it starts with the specific and ends with the general, whereas in accordance with the principle of progressive differentiation, the most general and inclusive ideas should be presented first.

This instructional model consists of "cycling" or going "up and down" from more general to more specific concepts and "backing up" again.

3. ANALYSIS OF MATERIALS

It is possible to achieve a meaningful learning by means of a process that relates, in a non arbitrary way, a piece of information with a relevant aspect of the individual cognitive structure. In this process, the new information interacts with a specific knowledge structure that already exists in the cognitive structure of the student.

Therefore, meaningful learning is not the product of simple association, but the result of interactions of different characteristics.

One of the important conditions to achieve a meaningful learning is that the learning material can be related and incorporated to the student's cognitive structure in a non-arbitrary and non-literal way. It is said that this kind of material is potentially meaningful.

This condition involves two main factors: the kind of material: it must be logically meaningful or have a logical meaning; and in the cognitive structure of the student, there must be specific subsumption concepts with which the new material can be associated.

The process in which the logical meaning of a material or assignment becomes a psychological or real meaning would be achieved only if the conditions already mentioned are fulfilled and the student is willing to look for possible associations between the material and the ideas already established in his/her cognitive structure.

The teacher who elaborates and selects an instructive text for a specific subject should be able to identify the main concepts of his/her area of knowledge and to introduce them in a coherent way, following the inner logical aspects of the subject.

As regards the organization of the contents, the four of the above mentioned criteria able to be applied to different areas of knowledge are proposed: the use of organizers, progressive differentiation, integrative reconciliation and sequence organization.

Finally, we analyze written assignments, laboratory guides and obligatory text books used in Physics I, II, III and IV.

4. THE MODERN PHYSICS SITUATION

The contents of modern physics that we have analyzed in this paper are the following:

"Heisenberg's Uncertainty principle" it is one of the most quoted.

"Schröedinger's wave equation" because of its importance in mechanical wave problem solving

"Potential valley" as an example of the convergency among mathematical models, empirical bases and efficiency in real problem solving.

We will also analyze the contents from the "method" used by natural sciences and from the interpretation made from the process of development of a mathematical problem.

The Uncertainty Principle

When we ask students who has passed the subject, or those recently graduated or to engineers with some years in their career, about topics of quantum physics, they always mention the Uncertainty principle among other different topics. But it seems that the mere fact of remembering a topic is not enough, because a great percentage of these individuals, think that, with a well developed technology, they will be able to see the electron and other smaller particles. This shows that it is considered an instrumental impossibility and not as something characteristic of nature.

But there are other reasons for students to remember this principle or its name. The following reasons were identified:

The impact experienced by students while working in a determinant, rationalist and mathematically perfect science context, such as Physics.

Students choose the Uncertainty principle due to its singular, academic and poetic name.

The relationship expressed by this principle is very simple from a mathematical point of view, but in a physical context, it shows unacceptable implications. If a position is determined, it is impossible to know the speed. and there is a similar relationship between time and energy.
A problem cannot be solved without following a text where it is explained.

The Schröedinger's equation
The sample investigated was formed by students, graduates and engineers with some years in the career. None of them could write the Schröedinger's equation independently of time that is to say, the simplest expression of the equation.
Even though, class assistants of Physics IV teachers also forgot some terms during the survey.
Some of the possible reasons to this situation would be:
The wave equation was mechanically learned and assistants did not meaningfully incorporate it in their cognitive structure.
While trying to learn the wave function ψ, it happens the same. This function is not interpreted, its physical meaning is not understood and it would be easy to use it just as a mathematical function. The student wonders if this equation was created by an enlightened person or if there exist another method of doing the exercise.
These reasons produce a "cognitive noise" that the student try to solve by means of rote learning. Therefore, forgetfulness is an irremediable consequence.

The potential well
The way to introduce this problem can be described as follows: particles of different energy state flow from the infinity, passing through the potential well. What is the probability that some of them may be inside the well?

From a mathematical point of view the problem can be solved following consecutive steps that may conclude in the mathematical result of the equation. They can be summarized as follows: 1) to state the wave equation for the inner well area; 2) to consider the continuity between both wave functions of the frontier region; 3) to observe what are the boundary conditions; 4) to solve the differential equation trying to get as less constants (to be identified) as possible; 5) to repeat this procedure with particles with a lower, higher or the same potential energy state as that of the well. This expert-like algorithm should constitute the aim of the students in some weeks.

The problem from an empirical approach
This problem is very different from what students have already known about classical Physics, as well as from their previous knowledge. There may only be some intuition that the particles are likely to be inside the well.

5. RESULTS
Physics subjects of the engineering course are analyzed from two different points of view. On one hand, the duration of each subject, the number of classes, the frequency of laboratory activities, the number of experiments carried out and the average time for each conceptual unit are taken into account. The results of the quantitative analysis are shown below:
All Physics subjects at the National University of Comahue are semestral, with an average of 16 actual weeks. That means 14 practical lessons and the same number of theoretical lessons.
There are three term exams with one make-up test.
There are two or three activities done in the laboratory, were students carry out two or three kinds of experiments. These are extra time-table activities.
Each conceptual unit is developed every fortnight approximately.

On the other hand, a qualitative analysis of different categories is taken into account. We consider practical assignments, laboratory guides or instructions, students' textbooks and the teachers performance. Here we analyze the roles of the different actors in the teaching process, their activities and the group academic performance.

The solving problem practical assignment
For analysis purposes we use the following classification: supporting problems and the usage of the recently explained theory; exercising problems, which are solving models or techniques used in the basic steps for solving problems; research problems, where research methodology is carried out for solving different problems.
Instructions in Physics I (Kinematics, Dynamics and Gravitation) and Physics II (Heat, Optics and Fluids) include supporting problems and exercising problems and there are no research problems at all. Within these categories there are two subgroups: problems with quantitative data and "theoretical problems", which relate an unknown factor to non quantitative data or other

variables. These ones appear at the end of the practice instructions and, generally, they are neither solved by students nor included in tests.
In Physics III (Electricity and Magnetism) there are generally supporting problems and the results are quantitative.
In Physics IV (Relativity, Quantum Theory, Solids and Nuclear Theory) problems are intended to support the theory and results are quantitative.
Usually, problems are taken from the bibliography used by teachers, choosing from those which have an only result (which generally appears in the instructions). Teachers select those exercises that can be solved by most of the students, so that the expected supporting function is fulfilled.
Conflict situations, the use of different strategies, possible solutions or approaches, understanding and research of real case problems are not included.

6. LABORATORY CLASSES

Laboratory classes offer the opportunity to give meaning to scientific concepts, verify or question, use laboratory tools and build a mental image of the natural processes.
They can be classified in experiences, laboratory practice and research. Experiences include facts and phenomena in which laws and theories are applied (similar to supporting problems). Laboratory practice is aimed at learning techniques, using materials and tools (similar to exercising problems) and solving tool pitfalls. The laboratory context, climate conditions and many others help to enhance the teaching-learning process, although, in general, some teachers get nervous. Research is aimed at learning the methodology of the scientific work.
In this analysis, we can observe that, although a few exceptions, laboratory classes are related to the first case (experiences). From Physics I and Physics IV there is a significant decrease in student participation and interaction and in laboratory tool usage. They become mere passive observers of what teachers do.
To sum up, from this analysis we deduce that, in most cases, the materials are not designed by the teachers, but extracted from textbooks; that the mentioned criteria to elaborate meaningful material are not taken into account, and that those materials are likely to encourage a mechanical and rote learning. The material gives clues to students about the profile of teachers demands and offers some information as regards tests

7. CONCLUSIONS

The problems outlined here place the university teaching of modern physics before a dilemma that would be necessary to solve according to the prospects raised to the next century educational systems.
The central question here is: should we continue working on a limited and individualized teaching with a repetitive, rote and out of context learning, not very useful to deal with other subjects? Or should we think of other alternatives taking into account the current needs of prospective professionals?
Incorporating new technology in order to build knowledge should be one of the teacher aims. This constitutes a possibility to have some elements that help to think and improve teaching practices.
As regards the university curricula some authors propose to reflect "about a kind of curriculum that encourages a strong basic theoretical training, a critical-social training including the ideological-cultural dimension, and a strong technological-practical training".
It is important to ask here about the meaning of "a strong basic theoretical training". Does it mean the transfer of conceptual concepts regardless methodological aspects of teaching?, is it necessary that all the subjects (Physics in this case) organize their activities establishing a division between theory and practice in the traditional way?, and finally, should we foster learning strategies in students although that means to devote less time to do exercises?
From the present article we conclude and recommend to start thinking of a cooperative activity among Physics teachers so as to reflect about the selection of the best learning opportunities, to explain the objectives and their cooperation with other subjects, and to consider this and other issues related to the improvement of the university teaching.
We can also infer that the teaching methodology of theoretical concepts, such as the ones taught in Physics IV, do not help engineering students to do meaningful or comprehensive learning. It is impossible for them to be efficient in these fields. Nevertheless, their performance in problem solving is effective because they use limited cognitive tools such as algorithms that allow students to mechanize the problem solving and thus, reduce the activity to a supporting exercise. To sum up, we can deduce that there is a high percentage of students who experience mechanical an rote learning as the only possible solution to fulfill the academic requirements and to achieve their personal and professional goals.

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The various concepts of Modern Physics are arranged logically and explained in simple reader friendly language. For proper...Â The study was conducted in the context of a first-year physics course, Basic Physics IV, at the University of Eastern Finland during the spring semesters of 2011 and 2012. The course covers waves, optics and modern physics, following the textbook by Knight [9]. Approximately 100 students participated in the course in each of the two years. Despite the simplicity of the model, learning to apply it seemed to be difficult. Even if the basic assumptions of the ray model were explicitly discussed in the textbook (see pp 701â€“2 in [9]) and in teaching, this did not guarantee student learn English. Physics. Identifier. PhysicsForScientistsAndEngineersWithModernPhysics9thFullSolution. Identifier-ark. ark:/13960/t24b6r355. Scanner. Internet Archive HTML5 Uploader 1.6.3. Which engineering deals most closely with modern physics that can help my thirst for knowledge? Last edited: Jul 28, 2014. Related Career Guidance News on Phys.org.Â Why not just take some courses in modern physics? Unless you plan on doing research then no jobs I know of will be using modern physics or at least not to a great extent. Jul 29, 2014.