Evaluation in physics teaching:
make it an opportunity for further learning

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(Received 18 June 2009, accepted 31 August 2009)

Abstract

Evaluation is a key stage in all teaching-learning processes, but it usually demands significant efforts of preparation from students and teachers, not to mention that it is very time-consuming. The traditional model of evaluation prescribes that students must sit periodically to demonstrate that they can recite blocks of knowledge, and solve exercises and problems which usually resemble or refers to the same set of study cases presented in lectures, in the laboratory, or the textbooks. Thus conceived, evaluation is indeed lacking, particularly in physics teaching: Did the students just learn how to pass this exam? Pass without real learning!. In this work I present a set of new, heretical ideas concerning possible changes in physics teaching evaluation, namely: (i) exploiting the exams as opportunities for further learning, (ii) examinations as a way of acquisition of new knowledge, or learning new analytical techniques, and (iii) exams as an opportunity for the application of standard powerful tools which students learned in their previous mathematics and physics courses. I present evidence of the quality-of-learning discriminatory power of new model of evaluation. The changes proposed are partially supported by Herzberg model of psychological growth recently adapted and applied to physics education.

Keywords: Evaluation in Physics Teaching, Learning Models, Testing Strategies, University Physics Education.

Resumen

La evaluación, un proceso clave en la enseñanza/aprendizaje consume considerable tiempo y esfuerzo de docentes y estudiantes. El modelo tradicional de evaluación exige que los estudiantes deban someterse a pruebas periódicas para demostrar que pueden *recitar* conocimiento, y resolver problemas similares o que se refieren a los mismos casos tratados en clases, textos, o laboratorio. Esta concepción tradicional de evaluación es deficiente, en particular en la enseñanza de la física: *Se puede Aprobar sin Aprender*. Usualmente el estudiante sólo aprende como aprobar exámenes. Pocos esfuerzos se han hecho en la enseñanza de la física para cambiar este modelo tradicional. Aquí se presentan nuevas ideas que implican un cambio irreverente en evaluación: (i) utilizar los exámenes para aprender más, (ii) utilizar los exámenes para la familiarización del estudiante con métodos que él ha aprendido en cursos previos de matemática o física, (iii) considerar los exámenes como oportunidades para adquirir conocimiento *totalmente nuevo*. Presentamos esta nueva concepción de evaluación, basada parcialmente en el modelo de *crecimiento psicológico* de Herzberg, e ilustramos con ejemplos de evaluación en cursos de física general, intermedia y avanzada; presentamos evidencia del poder resolución que esta concepción tiene sobre la calidad del aprendizaje de los estudiantes.

Palabras clave: Evaluación en Enseñanza de la Física, Modelos de Aprendizaje, Estrategias de Evaluación.

PACS: 01.40.Ha, 01.40.Fk, 01.40.gb, 01.40.gf **ISSN 1870-9095**

I. INTRODUCTION

Did my students just learn how to pass this exam, or have they really learned their subject?. Is this candidate really bright to qualify for the degree, or is he just able to test well?. Does he not only act bright and test well but also indicate that he will continue to act bright in relation to his position or title?. These are legitimate questions that according to Herzberg [1] any concerned evaluator must answer when confronted with his evaluations. In physics teaching the concern of teachers as evaluators is, or must be, much greater than what these three questions imply. The concern for what our physics students are really learning is widespread in universities, colleges and among education authorities. It is a well documented concern [2, 3, 4]. Already, several decades ago major decisions were taken to confront the problem for improving the learning of physics at different levels, as exemplified by the famous *P.S.S.C.* Curriculum [5], the Nuffield Foundation Curriculum [6], and the Berkeley Course of Physics [7]. All efforts, at whatever level, lead of course to evaluating the results, *i.e.* evaluating the student's performance. Yet, still today the traditional forms of evaluation persists and predominate at large: students must sit to demonstrate that they can recite blocks of knowledge, and to solve exercises and problems which usually resemble or refers to the same set of study cases presented in lessons, classes and textbooks.

Only a few well-known efforts, have been made in the last 50 years, to change or improve the way we evaluate students performance in physics courses, either at university or at college level, an in the secondary school. For instance, in the 1950´s the *Continuous Evaluation* method was introduced in several countries [8] (among them Venezuela and the U.S.A.). It proved to be very effective, but as the adjective *Continuous* claimed, the method not only demanded a well-trained teacher in its application, but also demanded intensive and extensive additional work efforts from him; efforts that only a few were willing to do for different reasons (e.g. lack of academic recognition for that extra efforts, and no extra income received). In the seventies the so-called *Keller method* [9], or *Personalized System of Instruction* (P.S.I.) for the Teaching–Learning of physics made its appearance and became fashionable [a1]. Keller´s method is based on innovative ideas such as self–study at one´s own *pace* and repeatable, partial evaluations: Study Units were written and handed to students for their *personalized learning* and an individual test was administered at the end of each Unit. Unfortunately, sooner than expected *P.S.I.* declined, for whatever reasons, and derided by the traditionally oriented teachers that opposed it. But even changes in teaching and evaluation such as in the Keller method are not sufficient to promote *good quality learning*, learning lying in the *best learning* region (Fig. 1), of what I define as the two-dimension *Teaching-Learning Space* (by analogy with the Phase Space of Mechanics), and where the parametrized *teaching-learning* paths can be traced. In comparison, traditional evaluation only leads to *rote learning* in the region close to *zero learning* (Fig. 1). Related to the problem of evaluation in physics is the problem of the development of problem-solving skills by the students [2]. Traditional evaluation and rote learning simply means stagnation for any academic institution, not only in physics education.

Many other *hidden variables* are at play in the learning process of a science, for instance, *social environment variables* and the frequently forgotten, but extremely important *lecturer performance* are also at play, but these variables belong elsewhere.

After laying out some of the fundamental ideas that place the present work in reliable grounds, I will present below some of the results obtained by me in trying to apply examinations as opportunities for the students and teachers to learn more. The results belong to actual courses of physics taught at different levels and different sorts of university students.

I. EXAM–DRIVEN AND ROTE LEARNING

One of the most influential variables in science education is the powerful drive which examinations impose on the learning process. Unfortunately, this impulse is usually wasted. Wherever physics is taught, one finds that most physics courses are almost completely *exam-driven*, that is, *the one objective of students in such courses is to pass the exams*; the consequence of which is *rote-learning*.

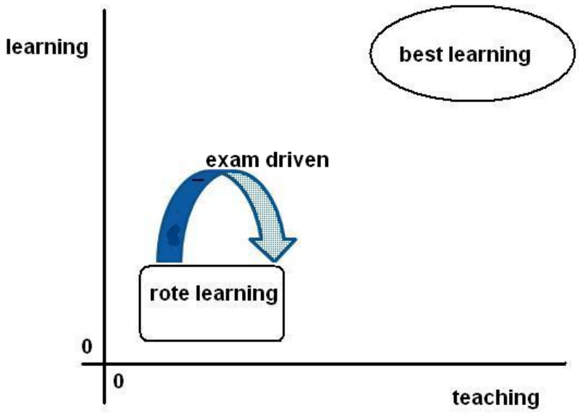

FIGURE 1. The traditional evaluation traces over the *exam-driven* curve and leads to *rote-learning*, close to zero learning. If the region of *best learning* is to be reached a different *teaching-learning curve* has to be defined and applied.

Worst even, usually neither the teachers nor the students are aware of that outcome. The traditional form or *Standard Model* of physics evaluation (and sure enough the traditional evaluation of any other formal or natural science) only leads to students preparing themselves to pass. The rest, including learning!, counts less or practically nothing. My findings, and opinion, in this important issue coincide with what others have also recently found [4]: "...students perceive that trying to understand physics well is an altogether different thing than trying to do well in the course". Traditional forms of evaluation not only emphasize the *Exam-Driven* parameter (Fig. 1), but in addition are highly inefficient, time-consuming activities, which blindly applied are a bad representation of the quality of the *Teaching-Learning* process. Partial evidence that this is so can be found in the concern of textbook writers themselves who have somehow felt the need to promote a better, or firmer, learning and have incorporated additional sets of truly motivating challenging problems, tens of back-of-envelope questions, and even home experiments at the end of their book chapters. Yet, the *Standard Model* of evaluation prescribes that students must sit mostly to demonstrate that they can handle exercises and problems, which closely resemble those, presented in the classroom, or even the simpler ones in the textbook. I firmly believe that, when done in that way, evaluation is an inefficient repetitive process, and most of the time a waste of time. It has become apparent to me that it is possible, with some extra effort on the side of lecturers, to convert exams into opportunities for further learning, and above all for improving the transfer of physicists skills to students. In passing, it may well be that this is not an altogether original idea. I am aware that there are physics lecturers and teachers at large who also exploit exams in better ways than the one defined by the *Standard Model* of evaluation.

III. A DIFFERENT TYPE OF EXAMS

Problems and exercises presented in physics exams to undergraduate students can be very difficult to solve, and at times very difficult to understand. Sometimes the single key difficulty lies in the tricky or lengthy solution of a purely mathematical problem lurking somewhere in the solving process of the problem. Those cases are not the subject of the present work (in fact many lecturers, including myself, object those type of problems as legitimate items for physics evaluation since such problems should instead be posed in a course of mathematics: *physics indeed is much more than mathematics*). It may also happen that the degree of difficulty when solving a physics problem lies in a chain of subtleties demanded by the solving process, and which the students cannot orderly handle. Neither these cases of evaluation are the subject of the present work. I object that type of evaluation items. My objection here is similar to the objection that an 800 meters track-athlete would pose, when his performance is assessed by asking him to qualify running first 100 m, then 200 m, then 400 m, and then 800 m. Having established what type of evaluation I am not referring here to, I now present the following set of 5 new postulates that should guide evaluation in physics courses [12]:

(i) Exams can and should be used as opportunities for further learning,

(ii) Exams can be used as opportunities for learning altogether new concepts and relations;

(iii) Physics exams can be used as opportunities of application of the powerful tools which the student has (or should have) mastered in previous physics and mathematics courses.

(iv) Examinations should provide opportunities for helping the evaluator to *discriminate the quality of learning of different students.*

(v) The role of the *Exam-Driven* variable (see the Introduction, Fig. 1) should be minimized.

These are postulates that define a new paradigm of physics evaluation. It is obvious that to evaluate physics courses, with exams based on one or more of these *commandments* is not an easy task. In fact it is considered heresy by many teachers, and they oppose changes as the ones prescribed by the postulates above. The teacher, or the university lecturer of General Physics courses has in addition to work extra in order to produce sets of problems, which depart from the traditional ones (for instance, you may have noticed that many problems repeatedly appear in all textbooks and in exams), some of which he should present in the Problems & Exercises sessions to the students. It is not that difficult for one to formulate truly motivating problems of Mechanics, Electro-magnetism or Optics; problems related to present applied physics, technology or say, to astronomy or molecular physics; problems that can be posed to science and engineering students. Apart from this, the lecturer should include in each exam one, or two problems that, once solved by the students, would represent the acquisition of a piece of new knowledge. I am firmly convinced that with such sort of questioning we can achieve success in the *Teaching-Learning Space* (Fig. 1), *i.e.* starting from zero to trace over a curve leading, or at least approaching, to the desired region of *best learning*.

In the case of an intermediate or advanced level physics course for physics majors, the evaluation should be planned along our same 5 postulates. It is absolutely possible to select fairly recent research topics in which the modelling has been done using the theoretical constructs taught in the advanced or intermediate course. For instance, in our Modern Physics I, or in the first Quantum Mechanics course, the problem of the motion of a *quantum object* (e.g. an electron, an atom, or a neutron) enclosed in a 1-dim or in a 2-dim box is mandatory. Today this problem can be easily exploited in connection with semi-conductor *quantum dots* and even *spintronics.* Another instance are the two-level quantum systems, usually considered more than once in quantum mechanics (e.g. the Stern-Gerlach experiment, the two-level atomic systems, and the set of 2×2 *Pauli Matrices*). This subject can be easily posed as a question related to a recent research application. In effect, Quantum Computation is a present, and interesting subject, which (adequately *trimmed* by the lecturer) can be posed as an exam question on two-level systems. This question can then be readily dealt with [10] the *algebra of Pauli Matrices, the concept of Unitary Operator and the Conservation of Photons*, and nothing more is required. Here you have an evaluation item which covers completely new knowledge for the student, but one which (s) he can cope with the tools mastered in the quantum mechanics course, and later feel very happy of having done so. Incidentally, some people consider Quantum Computation to be not feasible in practice (because of possible decoherence of the quantum states), yet it may still be seen as an elegant subject with a great conceptual charm [11] for students majoring in physics.

III. THE CASES STUDIED

For about 10 years the evaluation commandments presented in Section 2 have been applied to two types of physics courses by the author. Firstly, to 2^{nd} Year General Physics courses, common to Science and Engineering students. Secondly, at a considerable higher level, to honours physics degree students, attending courses of Non-relativistic Quantum Mechanics, Modern Physics, Waves & Optics, and even Intermediate Mechanics. Examinations for the first kind of courses lasted about 120 min and the population was about 50-70 students per term (72 lectures in 12 weeks). For the honours physics degree students the exams may last from 3 to 24 hours (24 h for *take-home* exams of Quantum Mechanics). Apart from lectures notes the students in both groups, could use textbooks, handbooks and calculators, even computers during the exams. The number of set problems was usually three per exam. At least, one of the posed problems *in each exam* was of the standard (traditional) type. The rest of the evaluation items were either of the type in which the students learn something new, or problems where some standard mathematical tool was in addition required to be applied in a form not previously taught during the course. Among such tools: the solution of an ordinary differential equation, integration of well known functions, series expansions, special functions, hyperbolic functions, critical points, variational calculus, and the like. Nothing really cumbersome, or tricky, has been ever proposed. In the harder cases, recall that I allow the students to use mathematical handbooks, and those cases always belong to 24 hour (take home) exams.

The reader should be informed that the number of students in my intermediate and advanced physics level courses has never been larger than 10-20, making it worthless to apply any statistical treatment to the results I present in Section V. In fact my series of three Quantum Mechanics courses have always been officially attended by no more than 8 students, usually only 4-5. This, incidentally, is the typical number of students majoring in "pure" physics at any university in Venezuela[1].

IV. ORIGIN AND FUNDAMENTALS

A. After a few years of observation of undergraduates in their physics courses at large, it became clear to me –as it has become clear to many others before– that there are indeed serious deficiencies in the final results of such courses [3, 4]. Just to mention some of these deficiencies: too few students realized that physics is a *natural science* devoted to the study of real phenomenae, many of them considered the problems and exercises only as kind of jigsaw-puzzles, only a few showed the skills typical of a physicist [2], and notably *too many students fail in physics courses*. I have tried –again as many others have– to solve these difficulties, fortunately with some success. Among the things I have done was to examine the exams. I realized that the examinations were a key point to investigate, and that lead me to try to formulate a different kind of examinations [12].

B. Herzberg Model of Psychological Growth

In the seventies I learned about the interesting but little known work of Herzberg [1], a psychologist who successfully studied the performance of employees and managers in large manufacturing firms from the 1940's to the 1960's. Herzberg recognized that the *intellectual development* and *psychological growth* of an individual can be *categorized*, in six stages, or *domains*, of growing complexity and increasing intellectual demands. I have adapted Herzberg model to physics education[1], an adaptation [13] that can be summarized as follows (see Fig. 2): the *Teaching Model* consists of five stages D_j of *learning* that satisfy the inclusion relation:

$$D_j \subset D_{j+1}, \quad j=1, 2,..5$$

and are to be reached in that sequence. The D_j stages are defined as follows:

(i) In the first stage D_1 of learning a student of physics is presented with the set of initial concepts $\{c_i\}$ of a given physics theory (as an example consider Newtonian Mechanics and the concepts or principles: *position*, *frame of reference displacement*, *time*, *velocity*, *mass*, and the *Principle of Inertia*). At this first stage a student is just becoming acquainted with that theory, and can hardly give a correct scientific explanation to a phenomenon that can be accounted for using that theory.

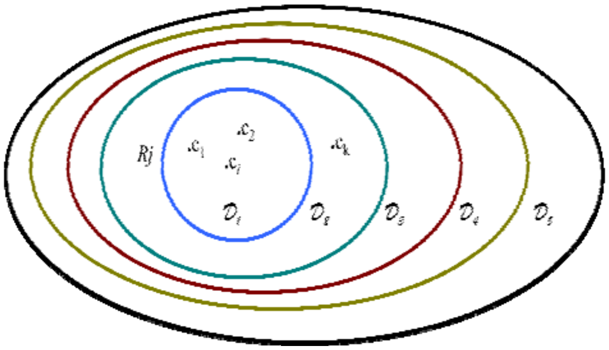

FIGURE 2. The five stages of learning as applied to the teaching of physics (based on Herzberg Model of intellectual development).

(ii) During the second stage D_2 the student learns the basic relations *Ri* of the theory (e.g. Newton Third Law) and new and more sophisticated concepts c_k, probably "constructed" with the initial concepts learned in stage D_1, e.g. *acceleration*, *impulse* and *momentum*, *kinetic energy* and so on. At this stage the student should be able to tackle elementary problems of mechanics or explain simple mechanical phenomenae, but he will be at difficulties in trying to interpret *by himself*, say, the motion of a pair of coupled oscillators, or the electro-magnetic waves standing in a cavity.

(iii) At the third stage D_3 (the *Creativity Stage*) a student of physics learns that new concepts and new relations can be defined anew with the *formal objects* presented to him in the two previous stages, and that he should have mastered by now. For instance he now may be learning about *Conservative Fields*, *Principles of Minimum Action*, *Forces and Gradients*, *Curls*, and perhaps *Lagrangians*. Yet, the main indicator that a student has reached stage D_3 is that he should also able to create or define new concepts and relations required, or convenient to define, in order to solve a physics problem or to interpret an observed physics phenomenon. Needless to say, that *this is the stage of*

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[1] An official policy of our physics department is to assign a single group of students (a section) to each lecturer. In case of larger Engineering&Science groups (50-70 students per section) the exams are prepared and run by committees of our physics department. These two policies make very difficult to run teaching experiments, or investigations, with our physics students. Only by exception I have been able to apply my own kind of examinations. Thus far students have never become aware of the study in which they have been involved. Many of them, particularly the ones majoring in physics, have been a *posteriori* informed by me of the results of the study.

learning, or of intellectual development, in which our physics students should ideally be after taking their physics courses: the Creativity Stage. Incidentally, this stage is called like that not because students are expected by then to have become researchers in physics producing *original work*, but only because the student is expected to create solutions previously unknown to him, not necessarily original ones.

(iv) Stage D_4 is called the *Ambiguity Stage*. In it the individual *is* confronted with the hardships of Nature and real world phenomenae. The latter are always ambiguous, with a plethora of confusing *varying* variables and parameters, whose relations are unknown, to be determined, and explained, by the observer. At this high stage of learning the observing student should have intellectually developed so much as to be able to discard negligible variables, to select the proper ones, and to construct his own working *physics model*, which he should also decide how to test in the laboratory, or with a computer simulation.

(v) In the final stage D_5 the student should have reached *Individuality,* in other words he should have become *independent*, and a leader. Being *independent* he can then even pose to himself new problems to be solved, or he can discover new phenomenae, that he is to solve with his own methods. It is the highest stage of intellectual development in learning physics. This is the expected stage of intellectual growth for researchers in any science.

When applying Herzberg Model to physics education and in particular to examinations as opportunities for learning more, I can make two points. First of all we notice that many secondary school and college physics examinations consists of sets of questions, exercises and problems that refer exclusively to stages D_1 and D_2 of Fig. 2. This is not altogether bad, since all of us need to learn the first things first, but certainly we cannot expect to see our students attempting to display the skills of a physicist if our courses and evaluations (in fact I should say our *physics curriculum*) are not directed to place the students learning processes in the *Creativity Stage D_3*. Secondly, when a set of examinations problems, including problems and questions as those I suggested in Section III, is posed to a group of physics students, the examination will readily discriminate among the students unmistakably classifying them in the Herzberg categories of intellectual development; and this is indeed valuable information for a teacher and an institution.

V. A SAMPLE OF RESULTS

A. Evaluation of a Physics-V course

The results of applying our postulates in Section III to the evaluation of the Quantum Mechanics courses for honours physics students were very good. Students never showed any kind of rejection or resentment. Instead they were rather successful, and have acknowledged in many occasions because I quote: “the exams were very hard but we really learned quantum mechanics at a very advanced level”. In fact many of the problems given to them were taken, or adapted, from recent research. With the 2nd. Year, General Physics for Engineering & Science courses, the results were again good, but definitely striking learning features appeared. Some resentment was also visible, as the students compare their own exams and marks with those pertaining to other classrooms (different lecturer, different section[1]). Yet, many engineering and science students were really pleased when confronted in my exams with problems related to recent technology, e.g. with digital cameras, orbits transfer of satellites, speed of processing in a cellular phone, optics communications and many other cases of physics application.

In the figures below we show an interesting case of our evaluations. The histograms show the marks obtained by about 60 engineering students in the first exam of Physics V (Feb. 2000). The subjects of the exam were Vibrations on Strings, Sound Waves and Pipes (including the 2nd. order differential wave equation for waves). The maximum obtainable mark was 30 point (10 points/problem). Question No. 1 required integration of a weakly exponentially decaying function (the density of a string of weakly variable density) and the total travel time of a narrow pulse in the string. It was also required to explain why the pulse has to be very narrow for pulse propagation in such string. The histogram for this question appears below in Figure 3. Although the group average mark is about 5/10, half of the class failed. The class was practically divided in two groups by the problem The discriminating power of the question is remarkable: it really showed who has really mastered travelling waves on a string, and was able to cope with an altogether new problem, yet still answerable with the physics and mathematical tools known to him.

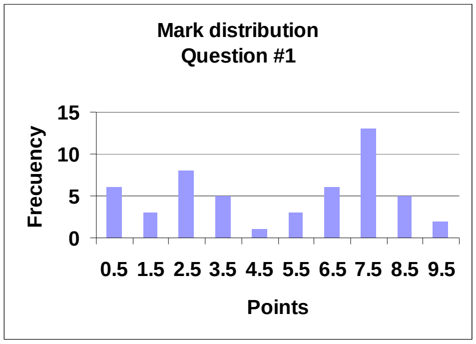

FIGURE 3. Frequency distribution of marks for Question No. 1 (First evaluation of a Physics-V course).

Question 2 of this first exam was typical of a traditional type of problem. Two algebraic formulas have to be combined into a set of two equations with two unknowns, and the system solved. The class now did very well as shown in Fig. 4 (about 30 students got 9 points out of 10). Only few students failed in this question. It in fact only demanded to “play” a kind of jig-saw puzzle with two blocks of variables (as many traditional problems just demand). One can easily note the difference with the results shown in Fig. 3. A traditional sort of question does very little as an evaluation tool: students can answer almost automatically, without really knowing the subject. The teacher could never know who has really learned the subject with a traditional question, as the student can easily trains himself to answer correctly such question without having learned anything. A traditional question discriminates little into those who have mastered a subject and those who have not.

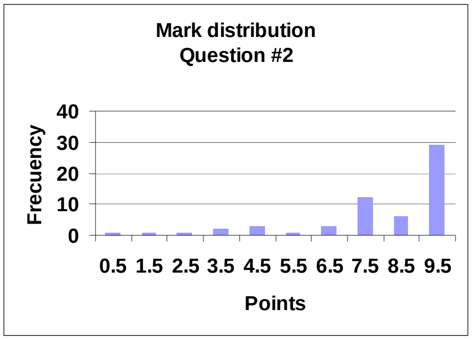

FIGURE 4. Frequency distribution of marks for Question No. 2. (First evaluation of a Physics-V course).

Results for Question 3 are shown in the histogram of Figure 5. It was a problem in which the concept of phase of a wave was the key point. The energy stored in part of the string has to be evaluated. The problem was innovative in the use of the concept of phase, rather than altogether different to what is printed in textbooks. As can be seen in the histogram only 17 students managed to solve this sort of new problem. It is evident that previous courses of physics have not given the students the opportunity to understand and exploit the important concept of phase of a wave (and the high-school mathematics used to handle it). The solution to this problem was later presented and thoroughly discussed in the problems session.

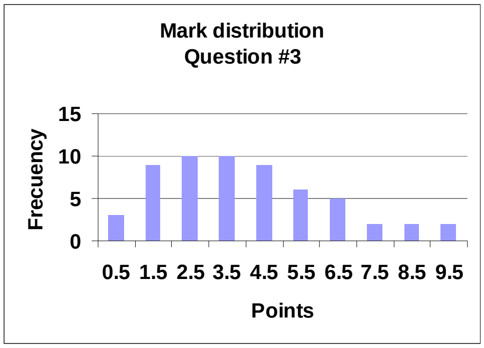

FIGURE 5. Frequency distribution of marks for Question No. 3. (First evaluation of a Physics-V course).

Finally, the histogram in Figure 6 shows the marks obtained by the class in the exam (the evaluation of student performance in the three problems). As a whole the class behaved almost *normally*. The histogram is roughly *Gaussian* shaped.

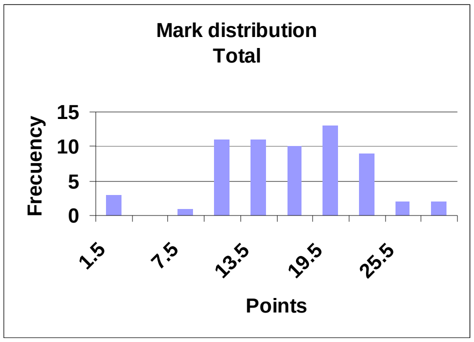

FIGURE 6. Frequency distribution of marks for the whole exam. (First evaluation of a Physics-V course).

B. Evaluation of a Modern Physics I course

The results presented in sub-section IV-A are really representative of what one should obtain applying physics exams following the postulates of Section III. Depending upon the natural differences of groups of students, depending upon the number of them, and of course depending on the teacher ability to create the three or four problems (these are the standard number of questions in physics examinations in my university) one will get marks frequency distribution similar to the histograms shown above. I would like to show the histograms for the results of an exam (the second of three) applied by me to a group of 21 students taking Modern Physics I (Nov. 2008). The contents of the exam were Atomic Models, Uncertainty Relations, Wavefunctions, Schrödinger Equation and its Applications to 1-dim potentials, Expected Values.

Figure 7 shows the frequency distribution of the marks obtained by the students in Question No. 1 which was a problem totally new to the students, but that could be solved using the theory, formalisms and problems presented to them in the lectures. The results are comparable to those shown in the histogram of Fig. 3 that correspond to a Physics V course.

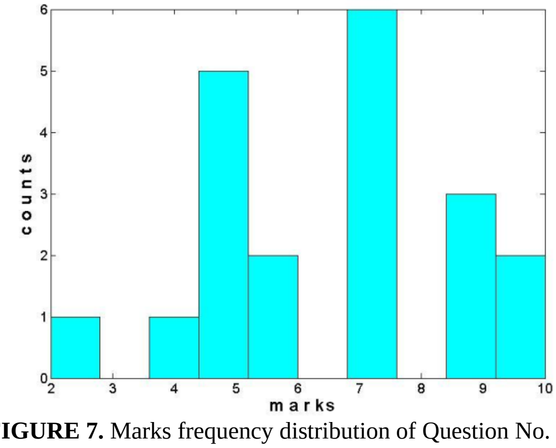

FIGURE 7. Marks frequency distribution of Question No. 1. (Second evaluation of a Modern Physics I course).

Figure 7 shows instead the marks distribution of Question No. 2. That was a traditional sort of question for whose solution the students only needed to apply known "formulas". The frequency distribution is seen now to be clearly biased towards mark 10, the maximum mark for the question. Only two students could not give the correct answer. I expected that result in the light of the model of learning presented in Section IV.

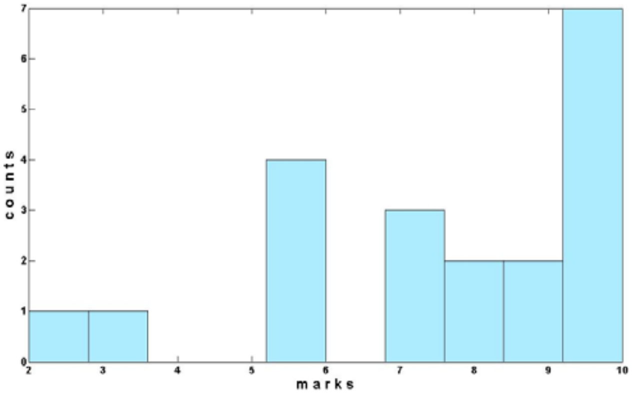

FIGURE 8. Marks frequency distribution of Question No. 2. (Second evaluation of a Modern Physics I course).

In Fig. 9 the frequency distribution for Question No. 3 is shown. This time the histogram is biased towards the lower marks. It resembles the histogram shown in Fig. 5. The problem posed in this question was also new to the students but demanded better solving skills and more creativity than Question No. 1 (histogram in Fig. 7) but the histograms for the two questions are not that different. The reasons for the similitude were given above, just at the beginning of the present sub-section: the results are going to depend upon the nature of the group of students and of course upon the nature of the questions. Clearly the class attending my Modern Physics Course in November 2008 was indeed a good one.

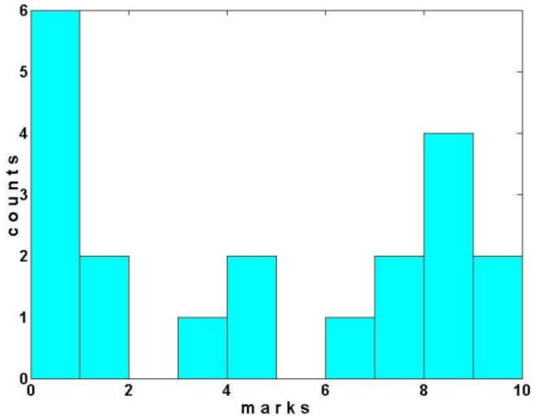

FIGURE 9. Marks frequency distribution of Question No. 3. (Second evaluation of a Modern Physics I course).

Finally, in Fig. 10 I present the frequency distribution marks produced by the students of Modern Physics I in their second exam. Only a few of the students fail to pass the exam. I believe that I succeeded teaching them the subject at a high stage of intellectual development; after analyzing the three examinations of these students, I am convinced that a good number of these students have reached stage D_3 of the model of learning presented in Section III.

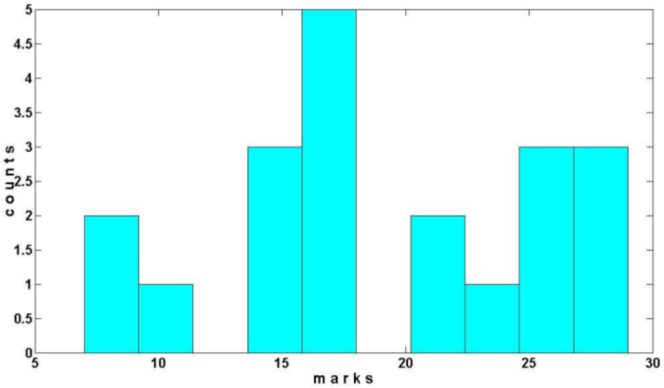

FIGURE 10. Marks frequency distribution of the whole exam. (Second evaluation of a Modern Physics I course).

VI. CONCLUSIONS

I have presented the fundamental ideas and a set of postulates for a new conception of student evaluation in undergraduate physics. It is partly based on a model of intellectual development for the teaching/learning process of physics that has also been presented in this work, and shown to be useful. The new conception of evaluation has been applied and tested along several years with consistent results in many courses of undergraduate physics, ranging from standard courses of University Physics to Intermediate and Advanced Quantum Mechanics, including Intermediate Mechanics, Modern Physics, and Waves & Optics for physics majors. The new evaluation method is powerful enough to easily discriminate among the students that simply intend to pass physics examination without really /learning the subject. I have shown that traditional ways of physics evaluation only leads to rote learning, and represented that case in a 2-dim *teaching/learning* space. I believe that our proposal for a new paradigm of evaluation has proved to be sound and provides consistent results. The application of the new evaluation conception demands extra and careful work from the teachers in order to create items of evaluation that are new and sometimes related to new technology and recent research. The latter have to be adequately “trimmed” if such results are to be posed as physics problems to undergraduates. The opinions of many students that have been evaluated using the new conception of evaluation are favourable. The new method of evaluation is very likely to meet strong opposition from lecturers and teachers affine to the traditional way of evaluating physics.

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