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CRITERIA WEIGHTING, BONUS AND PENALTY IN THE QUALIFICATION OF THE PHYSICS LAB PRACTICES: AN ASSESSMENT ORIENTED TO THE DEVELOPMENT OF THE COMPETENCES

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Abstract

This paper proposes a strategy of continuous assessment for the practice of physics that integrates three key criteria in the computation of the grade: weighting, bonus and penalty. On the one hand, the weighting of the different sections in the qualification allows us to prioritize educational goals and provides a first assessment of basic skills development, transverse and specific. On the other hand, the criteria for bonuses and penalties are applied as correction factors to refine the assessment of skills development in students. A case study in a subject of physics specialty Telecommunications Engineering Sound and Image shows the beneficial effect of this strategy of assessment on motivation and skills development in line with the model of the European Higher Education Area.

Keywords: Summative assessment, formative assessment, competences, European Higher Education.

1. INTRODUCTION

The adaptation of university to the European Higher Education Area (EHEA) represents a major challenge for innovative strategies which are required in the assessment of learning. This work proposes a strategy to evaluate continuously the physics lab practices combining three types of criteria in the computation of the qualification: weighting of the objectives, bonus and penalty. The weighting of the different sections is used to give more importance to the educational objectives and gives each a score based on relevancy. The sum of these scores is a note between 0 and 10 which must provide qualifications for primary, transversal and specific competences developed by the students.However the complexity of relevant competences in the EHEA difficult considerably get an accurate assessment by a simple weighting of objectives [1-2]. This fact has led to raise in this paper the use of additional bonus and penalty criteria which modifies the qualifications by adding or subtracting points in order to qualify and clarify the assessment of the competences. The implementation of this type of assessment in the lab practices of the subject “Physical Foundations of Engineering of Telecommunications Engineering” shows a clear beneficial effect on motivation and development of the competences in the students.

Among the aspects of university teaching that can decisively influence in the professional guidance of students it is especially important to make the assessment of learning based on a series of educational objectives properly preset for the development of the competences [3]. Thus, the assessment must be materialized in a series of objectives [4] through a systematic process in which one or more student characteristics are analyzed and evaluated in terms of benchmarks or assessment criteria [5]. In this systematic process of assessment we can distinguish three stages: first, an initial assessment that considers the previous knowledge and skills of students [6]; second, formative assessment which guides the students informing them of their successes and mistakes [7]; and third a summative or final assessment which gives a qualification that reflects the knowledge which students have reached [3]. In the final assessment assign a weighted qualification based on relevancy to the different objectives is necessary, so that the sum of these qualifications is a mark between 0 and 10 which reflects the level of development of the competences in students.

The main hypothesis of our work is that the summative assessment in physics lab practices can provide a more accurate measure of development of the competences in students with the application of correction factors which can raise or lower the qualification initially obtained by weighting the

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objectives. In this sense, the main purpose of this work is to properly define a series of bonus and penalty criteria that allow specifying and qualifying the qualification which focus on the degree of development of the competences of the students in a continuous process throughout the course. The variables involved in this approach are: structuring of the working folder or portfolio [8], working groups in the laboratory, prioritized weighting of objectives, criteria for the bonus and penalty in qualifying, final qualifications and motivation.

2. METHODOLOGY

Our work is developed is the context of the lab practice of the subject "Physical Foundations of Engineering in Telecommunications Engineering Sound and Image specialty. This is an annual course of 12 credits given at the first year of the degree in which the average age of students is around 18 years. The practice section of this subject has 3 credits and it is developed in the laboratory of physics in 15 sessions of two hours each, with a weighting of 20% in the final of the subject and the condition of compulsory attendance. In the laboratory there are several posts with experimental setups that students do in pairs or in groups of three, with a total number of students that can vary between 15 and 35 in each session. Each student has a portfolio which shares with his partner of practices and is the cornerstone upon which assesses in the following periods: each practice takes place in two sessions in which progress is evaluated continuously with the drawing up a lab report, which comes in the portfolio upon completion of the two sessions. In addition to the portfolio, students have the necessary equipment for conducting experiments as well as: computers with specific software for the calculation of errors, graph paper and printing standard graphical representations for the delivery of reports and questionnaires about previous practices.

In order to define the assessment process in this practice section of the course, the following seven objectives are established:

O-1: Understand the fundamentals of the Theory of Errors and apply them correctly to express the experimental measures with his mistakes and physical drives.

O-2: Acquiring preconceptions about each experience by reading the script and bibliographic information prior to its implementation in the laboratory.

O-3: Use proper and careful laboratory instruments in order to obtain accurate experimental measurements under conditions and predetermined error margins.

O-4: Understand the theoretical foundations and principles of the different experiences and apply them correctly to interpret quantitative and qualitative experimental results.

O-5: Argue and justify the experimental results and the potential consonances and dissonances with the theoretical approaches of each experience.

O-6: To present the theoretical and experimental results and the discussion of them in a legible and orderly in reports following the guidelines of the scripts of every experience in pre-established deadlines.

O-7: Participate actively and with motivation in performing each experiment in groups of two or three students equitably distributing the work among members of the group, laying the foundations for a cooperative work.

In order to illustrate the orientation of these objectives in the development of skills in students, Table 1 shows some specific examples of relationships between objectives and skills addressed in the new degree of Engineering of Image and Sound:

Table 1. Relations between objectives and responsibilities of the new degree of Engineering in Sound and Image

Objective(s)	Competence	Description of the Competence
O-1, O-4, O-5	Basic	Understanding and mastering the basics of the general laws of mechanics, thermodynamics, and electromagnetism fields and waves and its application for solving problems of engineering.
O-2	Specific	Ability to use tools to search bibliographic resources or information relating to telecommunications and electronics.
O-3, O-6	Transversal	Ability oral and written. Ability to plan and undertake tasks in meeting targets and deadlines.
O-7	Transversal	Ability to work in groups.

The design of the evaluation criteria starts with a weighting of objectives in order to obtain a score between 0 and 10 for each pair of lab sessions as well as for the report for each practice. To this end, it is considered a series of sections directly related to the objectives, which is assigned a score as follows:

- Criteria weighting for the first session of each practice (Note S1):
  - Correction and timely delivery of the questionnaire prior to each practice: 30% associated with the target O-2.
  - Numerical correction of direct measures: 40% associated with the target O-3.
  - Correction numerical of indirect measures crucial to understanding: 10% associated with the objectives O-4 and O-5.
  - Annotations in the portfolio, interest and motivation: 20% associated with the objectives O-6 and O-7.

- Weighting criteria for the second session of each practice (Note S2):
  - Numerical correction of direct measures: 20% associated with the target O-3.
  - Correction numerical or indirect measures: 20% associated with the target O-4.
  - Reasoning and answering to the questions of the screenplay which are essential to the understanding of the practice: 30% associated with the objectives O-4 and O-5.
  - Presentation of tables and graphs: 20% associated the target O-6.
  - Attitude and motivation in the laboratory: 10% associated with the target O-7.

- Weighting criteria for the report of each practice:
  - Numerical correction of direct measures: 15% associated with the target O-3.
  - Correction numerical or indirect measures: 20% associated with the target O-4.
  - Calculation errors: 25% associated with the target O-1:
    - Direct measures: 7.5%.
    - Indirect measures: 17.5%

- Justification and critical analysis of the results: 30% associated with the objectives O-4 and O-5:
  - Intermediate justifications and reasoning: 10%
  - Justified responses to the questions of the script: 20%
- Presentation of the report (tables, charts, development, etc.): 10% associated with the target O-6.

The weight criteria set out above provide three letters between 0 and 10 for each practice according to the degree of compliance with the objectives: a note S1 of the first session, a note S2 for the second session and a note for the report I end of practice. On this basis weighted rating establishes the following bonus criteria and / or fees:

- <u>Bonus and / or penalties for work performed in the laboratory (B)</u>: At note I of each report is added the number B given by the formula:

$$\mathrm{B} = \frac{S1+S2}{10} - 1$$

  - If the average score of the two lab sessions is greater than 5, then B> 0 and therefore I improve the note of the report to +1 point.
  - If the average score of the two lab sessions is less than 5, then B <0 and thus are penalized by lowering the note I report to -1 point.
  - If the average score of the two lab sessions is exactly equal to 5 then or allowances or be penalized, since in this case B = 0 and the note of the report remains unchanged.
  - If the note is a practice more than 10 once the bonus B together, such excess is counted as bonus note for other reports.

- <u>Exercise exclusive bonus (E1)</u>: This is an exercise that students perform in the first practice sessions devoted to theoretical and practical study of calculation errors. This exercise was done in the context of initial or diagnostic assessment to identify students' preconceptions. Note S of the exercise is obtained by applying the same criteria as in the first practice session, and from this letter S is added to the final grade of E1 practice a positive number given by:

$$\mathrm{E1} = \frac{S-5}{20} + \left|\frac{S-5}{20}\right|$$

  - If the note S for the year does not exceed 5, then E1 = 0 and therefore does not pick up or discharge the final score.
  - If the note S the year is over 5 then is added to the final grade E1, which can be worth up to 0.5.

- <u>Practical up note (E2):</u> This is an initial practice has aims to motivate students by offering the possibility of raising the final note of practices as well as prepare for the dynamics of subsequent practice. The practice note E is obtained by applying only the evaluation criteria for a report. From the note E of this practice note is added to the final practice E2 a positive number given by:

$$\mathrm{E2} = \frac{\mathrm{E}-7}{6} + \left|\frac{\mathrm{E}-7}{6}\right|$$

  - If the note E, the practice is less than or equal to 7 then E2 = 0 and therefore not pick up or lower the final grade for practice.
  - If the note E, the practice is more than 7 then added to the final grade of E2 practices, which can be worth up to a point.

- Penalty for improper use of physical units: the systematic use of the units wrong can waste a note of up to 50% in each item concerned in the two practice sessions and up to 80% in the report of each affected practice.

Note P of each lab is derived from notes S1 and S2 of the two sessions in which they performed as well as I note the report by the formula:

$$P = I + B = I + \frac{S1 + S2}{10} - 1$$

The final grade is derived from practices of the average of bonuses totalling practices E1 and E2 and limited to a maximum of 10 qualifying points, namely:

$$\text{Final score of practical sesions} = \min\left\{\overline{P} + E1 + E2,\ 10\right\}$$

3. RESULTS

This section presents the results obtained by applying our strategy of evaluation in a practical group of the course "Physics for Engineers", considering as main variables the final score of practices and bonuses E1 and E2 and the bonus / average penalty $\overline{B}$ for each student in the course of carrying out the practice. The results show a highly score due to a high level in achieving the objectives by students, which also show high motivation reflected in the high bonuses obtained.

Table 2 lists the final grades, E1 and E2 bonuses and the bonus / penalty average $\overline{B}$ for each of the 26 students of a practical group. All students passed the practices with a score greater than or equal to 7.4 except for a student who left practice when he only made the first practice. In addition, a total of 12 students earned the highest rating possible and others 5 students awarded a mark between 9 and 10, as a result of an extraordinary fulfilment of the objectives. Figure 1 shows the percentage distribution of scores for Table 2, being able to point out that 65% of students scored outstanding or the maximum score of 10.

Table 2. Ratings and bonuses / penalties average for a practice group where our evaluation strategy was applied

STUDENT	SCORE	E1	E2	$\overline{B}$	STUDENT	SCORE	E1	E2	$\overline{B}$
Student 1	**8.6**	0.4	0.6	0.4	Student 14	**10**	0.5	0.9	0.6
Student 2	**7.7**	0.2	0	0.6	Student 15	**10**	0	0	0.5
Student 3	**10**	0.5	0	0.8	Student 16	**8.6**	0.1	0	0.4
Student 4	**10**	0.3	0.5	0.7	Student 17	**10**	0.5	0.9	0.4
Student 5	**10**	0.2	0.7	0.8	Student 18	**9.6**	0.2	0.2	0.4
Student 6	**7.4**	0	0	0.4	Student 19	**10**	0.5	0.5	0.8
Student 7	**10**	0.5	0	0.8	Student 20	**10**	0.5	0.5	0.8
Student 8	**8.3**	0.1	0.6	0.3	Student 21	**8.4**	0	0	0.7
Student 9	**10**	0.5	0.6	0.8	Student 22	**9.3**	0.3	0.3	0.8
Student 10	**9,9**	0.5	0.2	0.5	Student 23	**9.4**	0.4	0.3	0.8
Student 11	**8.5**	0.2	0	0.7	Student 24	**10**	0.5	0.2	0.6
Student 12	**8.5**	0.2	0.1	0.2	Student 25	**10**	0.5	0.6	0.8
Student 13	**NP**	0.3	0	-1	Student 26	**9.5**	0.5	0.2	0.3

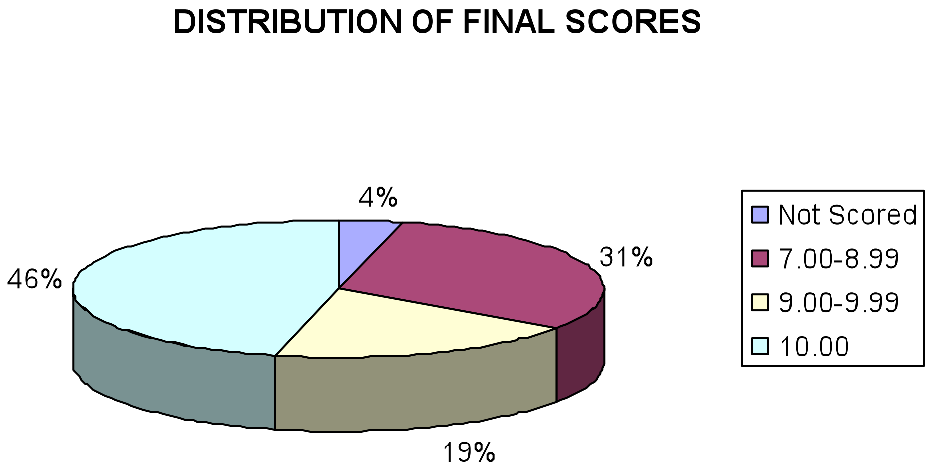

Fig. 1. Percentage distribution of scores for Table 2

On the other hand, Figure 2 shows the absolute frequency of the correction factor averaged over the conduct of all practices. It is noted that the most common value was +0.8 and the vast majority of students received bonus less than +0.4. The only penalty was due to truancy, which indicates that all students who attended were bonus practices based on this criterion.

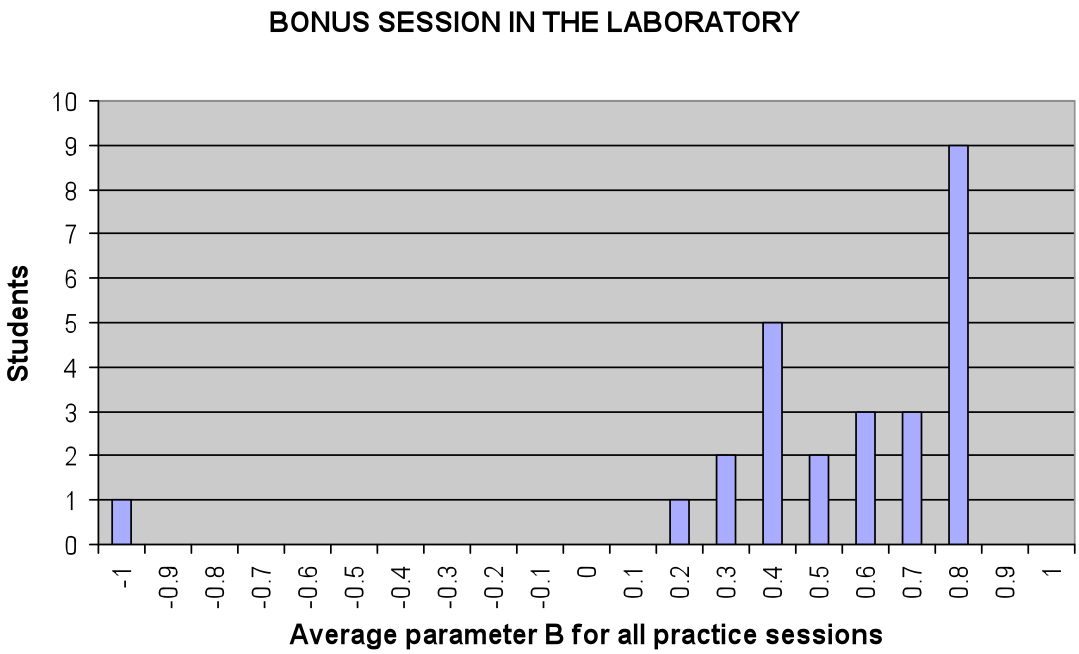

Fig. 2. Absolute frequency factor bonus / penalty averaged across all practices

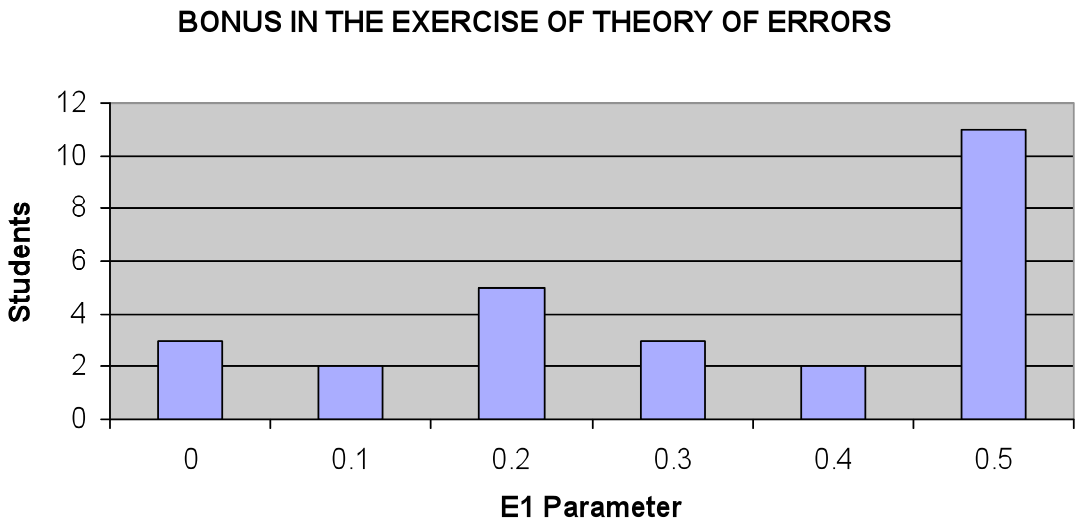

Fig. 3. Absolute frequency of the bonus factor E1

Finally, Figures 3 and 4 show the absolute frequencies for the bonus criteria E1 and E2 respectively. In the case of the E1 parameter it shows that the most frequent score was the highest of +0.5, which again reflects the high degree of motivation of students even in a first activity-oriented initial diagnostic evaluation. On the other hand, the bonuses obtained for the parameter E2 are significantly lower due to greater demand which is established with a cut-off equal to 7. Nevertheless, it is worth noting that 17 students scored in this section and even two students scored close to maximum.

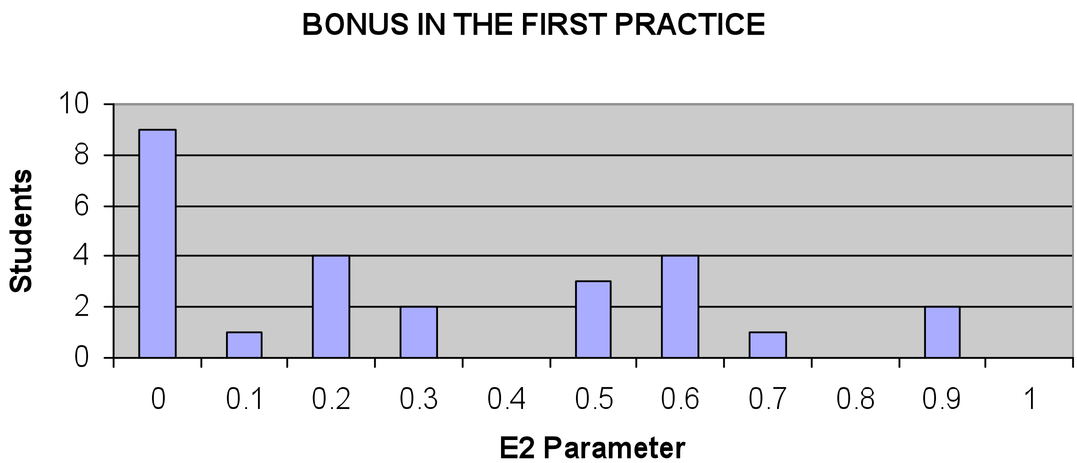

Fig. 4. Absolute frequency of the bonus factor E2

4. CONCLUSIONS

The high number of scores and bonus shown in the previous section show a beneficial effect of our assessment strategy on student motivation. The achievement of educational goals by students not only gave rise to excellent grades, but also helped to confirm the development of basic skills and specific cross certification such as those detailed in Table 1. In particular, through joint activities in the portfolio of practices and evaluated the strategy described, the students showed:

- Understanding the basic concepts of mechanics, electromagnetism and waves and their application to specific problems of engineering.

- Ability to use computer resources in literature searches to acquire previous ideas about each practice.
- The correct way to express themselves in writing reports using the appropriate scientific and technical language.
- Ability to work in groups and equitable distribution of work among the members in the context of a cooperative work and a great capacity for conflict resolution and prevention.
- Ability to plan and organize work and to meet deadlines for all activities, thus achieving the corresponding bonuses.

All the skills listed above could be detected and identified in specific situations: students completed successfully the questionnaires prior to each practice, worked together in an efficient manner, meeting all deadlines, etc.. This fact suggests that our evaluation strategy provides a means to measure skills development in students more accurately than a simple weighting of objectives. Moreover, our evaluation strategy led to a motivating environment in which students raised some interesting issues beyond the actual agenda: theoretical and experimental studies about the behaviour of large swings pendulum angle or estimate the magnetic force on the experience of law Lenz. This fact makes us think that our evaluation strategy can also be beneficial to encourage self-employment and student semi-autonomous within the EHEA.

As a final assessment include the interest that would be the extension of the proposed strategy in broader areas of assessment such as a full subject. We believe that the general methodology of our evaluation strategy to different subjects is an interesting problem in the context of educational innovation.

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