# SELF LEARNING AND SELF EVALUATION EXERCISES DATABASE IN BASIC MECHANICS: A THEORETICAL-PRACTICAL APPROACH

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## Abstract

In the School of Mines of the Technical University of Madrid (UPM) the first course of different degrees has been implemented and adapted to the European Higher Educational Area (EHEA). In all of the degrees there is a first semester course which gathers all the contents of basic mechanics: from the first kinematics concepts to the rigid solid plane motion.

Before the Bologna process took place, the authors had established the final assessment of the theoretical contents through open questions of theoretical-practical character. In the present work, the elaboration of a wide database containing theoretical-practical questions that students can access on line is presented. The questions are divided in thirteen different questionnaires composed of a number of questions randomly chosen from a certain group in the database. Each group corresponds to a certain learning objective that the student knows. After answering the questionnaire and checking the grade assigned according to the performance of the student, the pupils can see the correct response displayed on the screen and widely explained by the professors. This represents a 10% of the final grade. As the student can access the questionnaires as many times as they want, the main goal is the self-assessment of each learning objective and therefore, getting the students involved in their own learning process so they can decide how much time they need to acquire the required level.

Keywords: Self-learning, self evaluation, mechanics.

## 1 INTRODUCTION

The Spanish Universities are carrying out the adaptation process of their bachelor degrees to the European Higher Educational Area (EHEA) principles [1-3]. Within this process, in the School of Mines in the Technical University of Madrid (UPM) a methodology has been developed for a course named as Physics 1 taught in the first semester of two different Engineering degrees. The contents of the course correspond to an introductory Mechanics Course.

The adaptation process implies changes in instructional methodologies which should facilitate the deepening in the main ideas of the course [4]. The instruction process is determined by the educational objectives, the profile of the students, the instructional strategy, and the assessment method being applied on the course [5]. The profile of the students in the first year is very heterogeneous not only in their previous scientific knowledge but also in the level of motivation, that is, in their attitudes and aptitudes.

In a higher education context, the teaching-learning process should try to reach the learning objectives of medium-high cognitive domain, this means apply, analyze, evaluate and create according to the revised Bloom's Taxonomy [6-8].

A certain methodology has been chosen. It clearly establishes the steps for a personalized work, with self learning and self evaluation, so that the student can assess the level of success in his learning process in each objective, being able to decide personally to reinforce his learning until reaching a sufficient level.

The process is accompanied by a continuous evaluation process. Each week, a certain objective must be reached, following the established schedule. The level of success obtained by the student in each objective is kept and makes up a certain percentage of the final grade which can help to continuously maintain the effort in learning.

For the students who have chosen the continuous evaluation it has been established that the final grade is calculated by adding the different grades obtained in the different components of the continuous evaluation and in the final exam. Both continuous evaluation and final exam represents 50


*ISBN:978-84-615-0441-1*

% of the final grade each. There is a restrictive condition which forces, in order to pass the course, to reach 1.5 points out of 5 in the final exam (equivalent to 3 out of 10). The continuous evaluation has 5 different components; some of them will be explained later.

In the global evaluation process of the course different aspects are considered, such as comprehension, application and analysis of the theoretical-practical fundamentals, problems solving and practical laboratory work. The course lasts one semester and a total of 15 weeks.

The students who have followed this methodology belong to two different degrees: Energy Engineering Degree and Mining Technology Degree. The total number of pupils is 340, all of them without previous university experience.

## 2 TOOLS FOR SELF-LEARNING AND SELF-EVALUATION

The number of students and the frequency of evaluation are two sufficient reasons to choose an on-line tool, which on one hand is more motivating for the student and on the other hand let him make the time dedicated to learning more flexible. Nowadays, the use of on line tools to assist teaching and learning is becoming a common practice in universities worldwide [9-12].

In our University the e-learning software platform Moodle is used and permits a great variety of applications [13]. Each student has a personal user and password which allows him to access anywhere at any time by the Internet.

The course program comprises 15 topics, with a week duration, classified in 6 topics on Kinematics (Point Kinematics, Systems Kinematics, Rigid Bodies Kinematics and Relative Motion) 7 topics on Dynamics (particle dynamics, general theorems, kinetic, potential and mechanical energy, systems dynamics and rigid bodies plane motion) and 2 topics on Statics (plane rigid bodies statics). Each topic has a specific learning objective and a defined success indicator.

The student can access the questionnaires in Moodle and they are composed of several questions that he must answer. In the platform a questions database has been created, and the different questions are chosen randomly in order to create the questionnaires which will be displayed to the students, keeping in mind that all the questions of a certain questionnaire are referred to a certain learning objective and therefore to a certain topic. The questions have a theoretical-practical character and this implies they are not immediate answer questions, but a process of reasoning is required in order to response. Two parts can be distinguished in the questions: firstly a certain situation is presented and secondly a statement about that situation. The student must identify whether that statement is true or false. Just after answering, the correct response properly explained is displayed no matter the student response is. So he can compare his response with the teachers'. Occasionally the response includes links to other more detailed explanations which can be viewed by the student if necessary. Sometimes the response requires a certain numerical calculation.

The number of questions contained in the database is about 600.

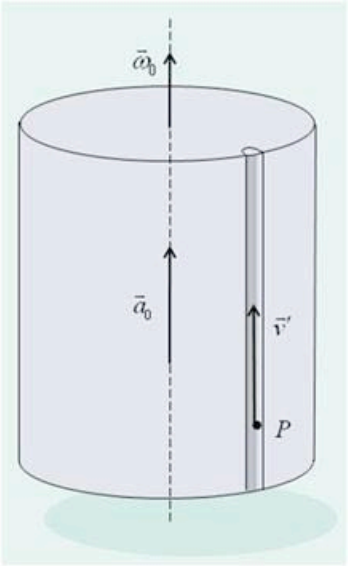
The questions database can be accessed along the semester so that the student can revise or deepen in those topics already explained in class or even for preparing the final exam. The student can check the grade obtained in each objective. And the result of this self evaluation process can help him to decide whether he has to take more time to learn certain concepts.

Nevertheless, the platform permits a period of two weeks for every topic (every learning objective), the first week the topic is explained in class, and the next week is the last one to complete the questionnaire and at the end of that week the grade obtained by each student will be registered. The highest grade obtained by the student is the one to be registered so in this way they will no bet afraid of repeating the questionnaires as many times as they want since the grade will never be lowered. When the period is over, the students can still access the questionnaires but the grade obtained will not be taken into account for this continuous evaluation component of the final grade.

This methodology has an advantage for the professor since it does not require work of correction as it is automatic [3]; it has been previously uploaded in the e-learning platform.

Below, we include three examples of questions, one from kinematics, one from dynamics and a statics question.

Example 1: Kinematics:



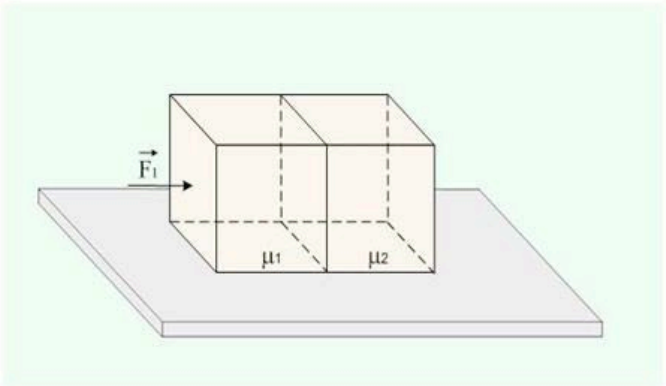

A certain cylinder can perform two types of motions, either rotating around its axis with a constant angular velocity $\overline{\omega}$, or translating with a constant acceleration $\overline{a_0}$ in the direction of its axis. We do not know which motion is the one performed by the cylinder. It is known that a certain moving point is going along a groove which is parallel to the rotating axis with a constant magnitude relative velocity $\overline{v}'$.

*It can be stated that if we are given the Coriolis acceleration of P, we can deduce which motion the cylinder is performing*

Fig.1: An example question on Kinematics

Example 2. Dynamics

Two blocks, both of them with a mass M, move together with a constant velocity due to the action of an horizontal force $\overline{F_1}$. The blocks have different friction coefficients along the plane, $\mu_1$ and $\mu_2$ respectively. Between the blocks there are two normal forces $\overline{F_{12}}$ and its and its opposite $\overline{F_{21}}$, both of magnitude $F_{12}$.

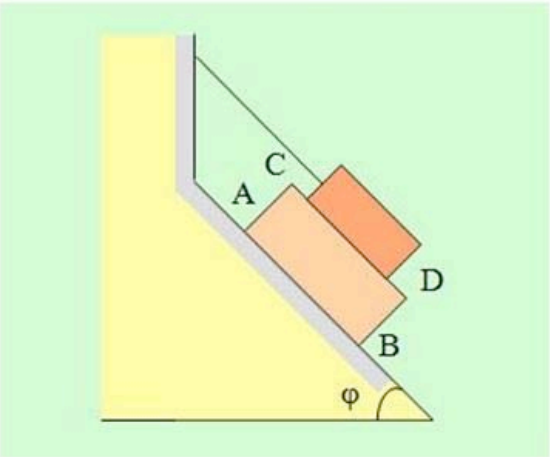



*If $\mu_1 > \mu_2$ the magnitude of $F_{12}$ is higher than if $\mu_2 > \mu_1$*

Fig.2: An example question on Dynamics

Example 3: Statics

A block whose weigh is $P_1$ lies in equilibrium over a second block, whose weigh is $P_2$ which at the same time is lying over an inclined plane tilted an angle $\varphi$ with the horizontal plane. The upper block is joined to the wall through a wire parallel to the plane.




One of the sides parallel to the plane of the lower block has no friction while the other side does have.

*The wire tension magnitude is higher if the side AB has friction and the CD one has not than the other way around.*

Fig.3: An example question on Statics

In every question, the student must think over whether the final statement (yellow text box) is correct or not.

The students who have chosen this type of evaluation also do two written tests in class along the semester, in which they have to answer two questions in each test. The responses must be properly reasoned. The first test is taken after kinematics ends and the second one, just after dynamics. These tests intend verifying the learning process, stimulating the student to finish his learning in the period scheduled and checking the written expression capability of the students. The questions chosen for these tests belong to the database, so the student do not have to do anything different from what he has been doing in his learning process and the probability of knowing the question gets higher if he has done many questionnaires before.

Also, in the final exam, together with the problems to solve, the students are presented four questions to answer, two of them from the database without any variation, one with certain modifications and a fourth one which is completely new and is not in the database. This group of questions weighs 50 % of the total grade in the final exam. Obviously, it can be stated that the continuous work done with the questionnaires along the semester favour the correct answer in the final exam.

At last, the students with best grades are offered the possibility of enhancing their grade. To do so, they must create 5 questions (two about kinematics, two about dynamics and one about statics) with their corresponding responses.

## 3 RESULTS

In order to evaluate the efficiency of the implemented methodology, the students have been classified into three groups depending on if they followed or not the programmed schedule for the questionnaires.

The first group is composed of the students who have answered all the questionnaires in the period of time fixed for it. The number of students of this group is quite high reaching almost the half of the total population. This group will be referred from now on as “High Engagement Group”

The second group is composed of the students who have answered all the questionnaires except one, two or three. This group will be referred from now on as “Medium Engagement Group”

The third group is composed of the students who have answered just a few questionnaires. This group is not divided in two as the number of students would be very low and it will be referred as “Low Engagement Group”

In table 1 the percentage of students out of the total in each group in shown.

Table 1: Number and percentage of students out of the total for each group of engagement

| | Number of students | Percentage % |
|---|---|---|
| Group1: High Engagement Group | 169 | 49,7 |
| Group2: Medium Engagement Group | 92 | 27,1 |
| Group3: Low Engagement Group | 79 | 23,2 |

In the table below, the percentage of students in each group who have passed the course (success rate) is shown.

Table 2: Relationship between engagement and success

| | Success Rate |
|---|---|
| Group1: High Engagement Group | 71,6 % |
| Group2: Medium Engagement Group | 57,6 % |
| Group3: Low Engagement Group | 11,4 % |

In the third table, the average final grade in each group is shown.

Table 3: Average final grade for each group (grade over 10 points).

| | Average final grade |
|---|---|
| Group1: High Engagement Group | 5,7 |
| Group2: Medium Engagement Group | 4,5 |
| Group3: Low Engagement Group | 1,5 |

The average grade obtained in the questionnaires by the students is shown in table 4.

Table 4: Relationship between engagement and questionnaires grades over 1

| | Average grade in the questionnaires (over 1) |
|---|---|
| Group1: High Engagement Group | 0,97 |
| Group2: Medium Engagement Group | 0,82 |
| Group3: Low Engagement Group | 0,26 |

It is expected to have a correlation between the type of group and the grades obtained in the two tests previously described, the first one taking place after finishing the kinematics topics and the second one at the end of the dynamics topics. The results obtained, averaging both tests in a scale of 20 points are shown in table 5.

Table 5: Relationship between engagement and the average tests grades. Grades over 20 points.

| | Average tests grades |
|---|---|
| Group1: High Engagement Group | 12,3 |
| Group2: Medium Engagement Group | 10,6 |
| Group3: Low Engagement Group | 3,1 |

At last, a correlation between the type of group and the average grade obtained in the theoretical-practical questions of the final exam. The results obtained are shown in table 6 and the grades are expressed in a 40 points scale.

Table 6: Relationship between engagement and the average grade obtained in the theoretical-practical questions in the final exam. Grades over 40 points

| | Average grades in the theoretical-practical questions in the final exam (over 40 points) |
|---|---|
| Group1: High Engagement Group | 18,8 |
| Group2: Medium Engagement Group | 14,6 |
| Group3: Low Engagement Group” | 4,3 |

Table 6 reflects the studied relationship and a high level of difficulty in this part of the exam.

If this analysis is repeated but taking into account only the theoretical practical question which is completely new in the exam (not included in Moodle and therefore not seen by any student previously) the results for every group is shown in table 7 and as it can be seen, they are coherent with previous results.

Table 7: Relationship between engagement and the average grade obtained in the new theoretical-practical questions of the final exam. Grades over 40 points

| | Average grades in the new theoretical-practical questions of the final exam (over 40 points) |
|---|---|
| Group1: High Engagement Group | 20,8 |
| Group2: Medium Engagement Group | 15,5 |
| Group3: Low Engagement Group | 5 |

In the chart of figure 4, all the information contained in tables 2-7 is summarized in a radial plot and the grades normalized over a 10 points scale.

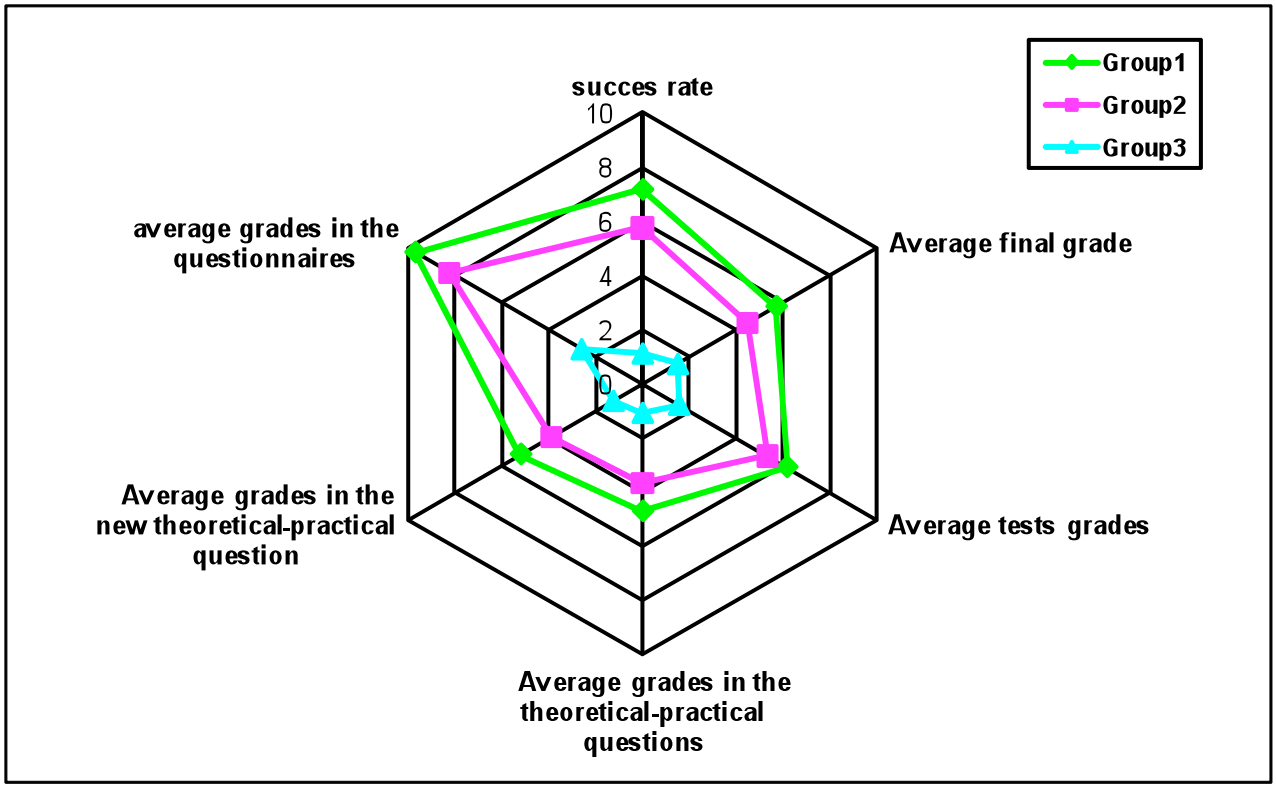



Figure 4: Chart containing all the results presented in tables 2-7.

Once the course is completed and the final grades are known, an online survey was performed requiring the students their opinion on certain aspects of the continuous evaluation process. 71 students answered, 70 % of them had passed. About this methodology the following question was asked: Do you think that the Moodle questionnaires have helped you learning? The responses are shown in table 8.

Table 8: Students responses in the survey.

| | |
|---|---|
| A lot | 49% |
| Quite | 37% |
| Little | 11% |

The acquired learning through the individual work with the questionnaires has an influence in the different components of the summative evaluation.

## 4 CONCLUSIONS

The global results obtained are considered to be satisfactory, keeping in mind this is a first experience. The application of this methodology must continue in following years.

There are different possibilities to improve the methodology and they are described as follows:

The students should follow the methodology completely. It is not enough with a global training to reach a high level of reasoning, because each topic has basic ideas which must be analysed by the student. Students should not leave questionnaires undone. It is important to motivate and encourage students in order to overcome the current 49.7 % of students who have completed all the questionnaires.

It is convenient to increase the number of questions that compose the database, especially in the questionnaires with a lower number of questions available, in order to diminish the probability of repeating the same questions.

Calculated questions should be created in those questionnaires which do not have them now, so that every questionnaire will have at least a numerical question which obliges the student to calculate. This will improve the calculation capability which on one hand is basic for problem solving and on the other hand the probability of random correct answering is diminished.

The best questions invented by the students can be included in the database, indicating the author, if he permits so, which can motivate the best students to go farther in their learning process.

Let the students post a comment on the questions of the database such as what the most difficult part was, or if the question is clear enough or not, etc. So in this way there is a feedback on the learning-teaching process.

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