Implementation and evaluation of an effective computational method that promotes the conceptualization of Newton’s laws of motion

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Abstract. A computational method that contributes to the understanding and conceptualization of Newton’s laws of motion, through the use of a novel environment of virtual experimentation of physical systems, was implemented in the students of the Faculty of Engineering and Basic Sciences of the Universidad del Magdalena. This article investigates the level of learning achieved by implementing the physical experiences in the mechanical laboratory and the virtual laboratories developed in the Unity platform, which can be used by the user to work in web environment and mobile devices, when downloaded as an application in Google Play and App Store. Conceptual tests were administered to assess students comprehension before, during and after instruction. The results revealed that the experimental and virtual conditions were equally effective in promoting student’s understanding of the concepts in the domain of Newton’s laws of motion; therefore, virtual manipulation, at least in a context such as that of the present study, reveals an important method in the learning of physics.

1. Introduction

The technologies can promotes a better learning experience for the student and in this way promote perseverance through internal motivation, progress in learning is still difficult to achieve, although it is often believed to be an effective tool for instruction of self-motivation [1, 2]. In this regard, the ideal of computer-based teaching is to make learning an interesting and motivating process for students to reach their goals. Therefore, it is believed that computer-based instruction can offer advantages, such as at their own pace or self-regulated learning [3] that traditional instruction can not offer. Although there have been many studies that report in their favor [1, 4], there are still open questions: First, if is it able to provide to students a more attractive learning experiences? and, second, is its content in the same level with its skill or knowledge levels for self-regulated learning? We evaluate the level of learning achieved by students through the implementation of the physical experiences in the mechanics laboratory and the virtual laboratories developed in the Unity platform. The competence development in the students is determined by using tests before and after the interaction with the simulators based on a methodological approach of participatory action, where the student relates the scientific conceptualization with real events, in addition the results obtained by the students in the development of interpretive competences are compared, Argumentative and propositive in the
subject of physics through the implementation of simulations, with the historical performances achieved in mechanics tests in this specific topic.

2. Virtual laboratories of mechanism
One of the most important characteristics of the Unity in the development of our physical systems is the support to model physical properties, such as objects with mass, acceleration, force, time, launch angle, spring elasticity constant, etc. Objects can vary their aforementioned characteristics, using several types of parameters. The virtual laboratories are accompanied, by a structured guide as follows: Name of the laboratory, standard, skills to be developed, problematic question, curricular area, achievements to develop, performance indicators, theoretical foundation, simulation, observation of the phenomenon, calculations, results and analysis. For students to recognize the relevant variables of the simulated phenomenon, the relationship between them and the physical laws that explain the phenomenon.

2.1. Newton’s second law
In this simulation you have the possibility of varying physical parameters such as: the mass of the car, mass of the object that hangs, distance traveled by the car, from this information you determine physical variables such as strength, time, speeds and the acceleration of the system. From which users can determine the functional relationships between them that allow to verify what type of relationship exists between them. All this allows the student to recreate Newton’s Second Law, make graphics with the data thrown by the simulator and its respective analysis.

Figure 1: (Color online) Computational experiment of virtual laboratory to study Newton’s second law.

2.2. Projectile motion
Using the Unity platform recreates the parabolic movement in two dimensions, the input variables: Angle of elevation, height of the launcher, initial velocity of the projectile and the distance of the table are varied by sliding buttons throwing as output data the flight time,
horizontal and vertical displacement of the projectile. From this output information you can obtain the trajectory equation and characterize the type of movement.

![Virtual laboratory of the projectile motion experiment.](image)

**Figure 2: (Color online) Virtual laboratory of the projectile motion experiment.**

### 2.3. Energy of the simple harmonic oscillator

As in the movement of projectiles, the input variables: hanging mass, spring elasticity constant, amplitude and speed of the simulation, are modified by the sliding buttons located on the left and as output data have the elongation, acceleration, period, frequency, time.

![Virtual laboratory of the a block-spring system experiment.](image)

**Figure 3: (Color online) Virtual laboratory of the a block-spring system experiment.**

### 2.4. Implementation of virtual laboratories and pedagogical results

In this phase, we began with the detailed explanation of how to work Newton’s Second Law guide in their respective moments pedagogical dimension (competencies and competencies indicators), problematizing question, problem situation, software analysis, information gathering
and subsequent analysis both physically and mathematically, so that they promote their own learning and feel motivated to work in groups. At the initial stage a change was observed in the students, this can be attributed to the design of the didactic guide and the way of working always accompanied by the teacher, but in the same way to the pleasant form of the software, the motivation generated by the guide and the teacher and also by the relationship between the members of each laboratory group. It is observed that the students go into the analysis of the proposed situations, trying to propose solutions to them, and improving the performance for each competency that is intended to be evaluated through the software and the didactic guide, showing more clarity in points of view, argued not only mathematically but also physically, evidencing a change in the construction of mechanical concepts from their appreciations, improving the way of writing their results linking the language of the natural sciences. In order to obtain these results, the presentation of a scientific report was taken into account, as well as the post-test of the subject matter in question and to establish the performance levels which were established in order to complement the numerical score. that is given to each student making a qualitative description of the skills and knowledge they might have if they are located at a certain level (Orientation Guide Saber 11 grade 2017 pages 76-77).

Regarding the methodology used in the development of this research, a pre-test was applied which consisted of nine three items of interpretive competence, three of argumentative competence and three of propositive competence, this was done well in advance of the software application of virtual experience of the subject in question Second Law of Newton, the evidence was collected, tabulated and analyzed by traditional statistical methods and are located according to the levels established by the MEN for this type of competency-based evaluations, then by means of of the virtual experimentation software the teacher explained in detail the pedagogical guide and the guide was carried out completely (by groups), at the end of this phase the students were asked to prepare a scientific report with all the information developed in class. Subsequently, a post-test of the same style was applied and the results of the initial and final competency levels were compared, establishing that the virtual experimentation software had positively contributed to show a better level of competence in the students.

The class of physical simulations that becomes available to students who have to learn physics is large and diverse on web sites; we chose to focus our efforts on teaching students to learn Newton’s second law following a pedagogical method included in the systematic procedure in which the students makes graphics related with the phenomena and comprehend the results, which gives our virtual laboratories a plus compared to the simulations found on the web, which only focus on the visualization of the physical phenomenon. Students taking a typical introductory mechanics course would learn several motion prediction equations emphasizing kinematics, a way of describing the motion without explicitly connecting changes in the motion to forces (i.e., dynamics). Our virtual laboratories which include simulations such as projectile movement, spring mass system, variable force etc. they connect the laws of Newton, through the strengthening of the physical concept through the procedure proposed in the development of each virtual experience of mechanics. Nevertheless, we wanted to measure how effective is the use of virtual laboratories, students took a test during two weeks to evaluate student’s physical skills on Newton’s laws. Students received a methodological test that emphasizes on their previous knowledge reated to Newton’s laws, afterwards, the same test is solved by students. The result is shown in the Fig. 4, the use of virtual laboratories contributed to improve interpretative, argumentative and propositive competences, as we can see when comparing the results obtained between diagnostic and final test results.

3. Conclusions
Our work provides a touchstone example of computational study of Newton’s laws through virtual laboratories for the students of the Faculty of Engineering and Basic Sciences of
Figure 4: (Color online) The figures correspond to the diagnostic and final test applied to the students, which consists of ten questions, of which five (5) correspond to the interpretive competence, three (3) to the argumentative and two (2) to the propositive. The sample was of 40 students that was divided into two groups of 20 students each.

the Universidad del Magdalena. The results shown that the level of learning achieved by students grown through implementing the physical experiences in the mechanical laboratory and the virtual laboratories developed in the Unity platform. Our virtual laboratories taught students for solving analytic problems and understand the graphs of the results obtained from the computational experiment using virtual laboratories. We believe that students who could synthesize their analytic and computational skills would be better prepared to solve the open-ended problems they will face in their future work.

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