Development of cognitive competences in physics in students of Biology

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Abstract. A computational method that contributes to the development of cognitive competences, in students of biology of Magdalena University, is based on the use of a novel environment of virtual experiences of physical systems. This article investigates the level of learning achieved through the implementation of virtual laboratories that can be used by the user to work in web environments and mobile devices. Conceptual tests were administered to evaluate students’ competences before, during and after instruction. We present some perceptions and comments of the students regarding the virtual laboratories of Newtonian mechanics and we conclude on their effectiveness in the development of cognitive competences.

1. Introduction

Competency-based teaching provides students with the progression of their learning through their academic work towards mastery of generic competencies regardless of time, method, place or pace of learning [1, 2]. The competency approach can be used to develop skills (competencies) that are transferable across different academic disciplines, or beyond academia to the corporate sector [3, 4]. Physics courses may not be using knowledge of the concept of physics directly in their careers. However, the practice of learning physics contributes to the development of many other skills. Computing (the use of a computer to solve numerically, simulate or visualize a physical problem) has revolutionized scientific research, engineering practice and health sciences. In science and engineering, computing is considered to be as important as theory and experiment. Experiments that are impossible to perform in a laboratory are studied numerically or virtually. However, the use of the computer has grown (for example, the facilitation of tasks [5]). The use of computing in Newtonian physics courses has brought several potential benefits. Students can participate in the modeling process to make problem situations manageable. Students can also use computing to explore the applicability and usefulness of physical principles in their careers. In contrast, little is known about the role that computers can play as problem solving tools in mechanical physics courses for students of biological sciences. In a way, students who use virtual tools are participating in jobs that are more representative of what they will do as professional scientists so they must learn to contextualize problems in a way that produces an accurate representation of the physical model [5]. In particular, we teach students to use the virtual environment to build models that predict the physical systems under study. We design didactic-pedagogical guides and implement them simultaneously with virtual experiences. However, our study was designed to provide evidence of the effectiveness of virtuous experiences in the
development of competencies in students of biological sciences and their positive perception in the teaching of mechanical physics.

2. The virtual laboratories of Newtonian mechanics

As our society progresses in the accumulation of knowledge and as the complexity of this knowledge increases, it becomes more important to determine how to structure education to provide individuals with the most complete knowledge base without sacrificing depth and complexity or breadth of the material. Humans have an extraordinary ability to store large volumes of organized information in memory. How it applies So detailed knowledge of real-world problems and practical situations? What is the optimal mode of learning it will promote? Flexibility and transfer of general knowledge across domains during problem solving?.

A virtual laboratory can have a mainly pedagogical function, which allows learning concepts, laws and phenomena without having to wait a long time and without the need to invest in the appropriate infrastructure to perform these experiments. But it can also be used as a prediction tool to verify the data of an experiment or to design an experiment more complicated in which calculations cannot be easily made with a pencil and paper.

The type of design chosen for this study was the experimental pre-test-post-test (pre-test and post-test) and control group. At the beginning of the academic year of the complete list of students, two groups were formed, the experimental group (EG) and the control group (CG). The members of both groups were randomly assigned so that each student has the same probability of being chosen. The instruments used in this study were diagnostic evaluation, pretest and posttest. Diagnostic evaluation: instrument with state test type format, multiple choice with only one response (MEN Colombia), which collected information about the level of knowledge regarding basic Newtonian physics topics, which the student brings from previous levels, and included a Thematic points that are taken throughout the semester. The pretest: instrument, which collected information about knowledge. As for the posttests, the same questionnaire was

Figure 1: (Color online) Analysis of performance of the entrance tests to the Biophysics and Physics course in Biology, as well as the effectiveness percentages of the final tests.
used in order to determine the improvement of the expert topics during the course in order to measure the contributions that the simulator could offer for physics learning.

Figure 2: (Color online) Analysis of the questionnaire of closed questions, formed by 16 items, with the aim of collecting opinions outside the established questions, the items are written as affirmations in which it is necessary to indicate with a scale from 1 to 5, all the possibilities of answer, from the most opposite (level 1) to the most favorable (level 5).

The tool used as a stimulus was "http://simulacionfisica.unimagdalena.edu.co/" which has great versatility in terms of its possibilities of application in the classroom. The pedagogical teaching guides have a theoretical component and activities. It is extremely realistic, in 3D, and gives the feeling of being effectively inside a laboratory. It was developed by a group of engineers from the University of Magdalena and the Industrial University of Santander. The main advantages of these virtual simulations, compared to others available on the web, are that it is very dynamic, intuitive and contains a series of experiments to perform in five work tables, in addition the teacher can vary the conditions of the experiment as if it will be a real experience, which differentiates the topics to be addressed: Graphical analysis, kinematics in one and two dimensions, particle dynamics, friction, collisions and fluid static. It also allows the student to make decisions and make choices similar to those he would take in a real laboratory, experiencing the consequences of the correct or incorrect praxis without any risk.

The administration of the pre-test served as a control of the experiment, since when comparing the pre-tests of the two groups, the randomization of the groups was assessed as adequate and allowed to analyze the gain score of each group (the difference between the pre-test scores and the post test). In the first class of the 2019-I Entry course, both groups were simultaneously administered the diagnostic evaluation and the pretest. They were anonymous and designed the same for both groups. Respecting the planned in the curriculum of the physics area of the University. In figure 1 you can see the structure of the didactic-pedagogical intervention.
Subsequently, in a classroom of the University physics laboratory, virtual simulations were presented to the experimental group in general, in order to familiarize the student with the procedure to follow, a series of screenshots of the simulator was shown. Through them it was indicated how to find each virtual experience to start the simulations, how to access the laboratory and its respective practice and finally the student begins to work the guide that is like a kind of workbook accompanied by the teacher. In the simulation the student carried out basic operations of a real laboratory, following the protocol directed by the pedagogical intervention guide. Finally he completed some tables and from these he made different calculations to analyze them. With this data he completed the written report of the laboratory experience. The report was evaluated and delivered to the student in the next class.

Figure 3: (Color online) Analysis of the questionnaire of closed questions, formed by 16 items, with the aim of collecting opinions outside the established questions, the items are written as affirmations in which it is necessary to indicate with a scale from 1 to 5, all the possibilities of answer, from the most opposite (level 1) to the most favorable (level 5).

3. Application of virtual laboratories-pedagogical guide
The implementation of laboratory simulations has been carried out during the 2017 I-2017 II period; 2018 I-2018-II in courses taught to physics and biophysics students of the biology program, the methodological approach applied is that of participatory action where the student relates the scientific conceptualization with real events and the simulation of the physical phenomenon under study, with in order to evaluate their argumentative, interpretative and propositive competences. Three groups participate, one of physics that begins its courses in this area of knowledge one of biophysics that already received the previous course and a control group that will receive their courses without the use of the tool of the virtual laboratories.
The results obtained when comparing the input and output behavior of the three groups show us favorable results in the development of argumentative, interpretive and propositive competencies for students who have received their courses by applying the tool of the virtual laboratories. Correct results of their previous knowledge from 29% to 65% in physics and from 27% to 67% in biophysics, while the control group maintains the percentage of performance with which it started. Additionally, students express a positive opinion regarding clarity, the theoretical foundation of the material contained in the guides and the motivation generated by the problematic question, which increases the interest in participating in the experience. In our experience as a teachers who has worked with the physics and biophysics groups using the virtual tool for the development of these courses we saw an improvement in the qualifications or that is evidenced in a greater number of passes and an improvement in the way of posing the solution to problems as well as a greater interest in participating in laboratories. We can consider that the questionnaire is reliable and the statistical results are valid, if the index $\alpha > 0.7$ and the reliability of the internal consistency of the instrument can be estimated with Cronbach’s alpha (0.9). The measure of reliability using Cronbach’s alpha assumes that the elements (measured on a Likert scale) measure the same construct and are highly correlated, the closer the value of alpha to 1.

4. Conclusions
The students who received the physics and biophysics courses using the virtual laboratories, supported by the pedagogical intervention guide, showed a significantly high improvement in the development of a good attitude towards the study of these subjects, in addition it is observed that the learning material that provides the pedagogical guide, turns out to be potentially significant for them, since by developing different hypotheses about problem situations raised in the material, they allow them to confront possible solutions until they find the most pertinent, thus becoming active protagonists of the construction of your own learning. The students who used virtual laboratories as a pedagogical strategy in the development of their courses, when comparing the tests of the input and output behavior of the three groups show us a higher level of understanding of the laws and principles of physics, as well as an improvement in the development of skills to raise and solve science problems, than those with whom a traditional methodology was followed, the results show that the correct results of their previous knowledge of 29% to 65% in physics are passed and from 27% to 67% in biophysics, while the control group maintains the percentage of performance with which it started. One of the difficulties encountered in the development of this work is that the use of this type of methodology requires a teacher to constantly train in the management of virtual tools, because the greatest responsibility lies with it, since it must be the first to experiment, know how it works in order to direct and guide students in the construction of their concepts, and in this way the simulation of the experiment is as enriching and stimulating as possible. In conclusion, we can affirm that the use of this tool as a methodological strategy in the development of physics and biophysics courses is helping to improve the development of competencies for the interpretation of a physical phenomenon.

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5. References
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