Virtual laboratories of electromagnetism for education in engineering: A perception

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Abstract. The influence of virtual tools as didactic means towards the study of electromagnetism phenomena takes greater relevance every day at the Universidad del Magdalena due to the inclusion of a visual and dynamic element beyond the reading of physical text books and even the development of laboratories real electromagnetism. This article shows a very positive perception on the part of the engineering students regarding the advanced virtual laboratories of electromagnetism, influencing the learning of physical concepts and the development of cognitive competences. Students' understanding of the concepts of physics in the domain of electromagnetic physics was evaluated in a pre- and post-test design involving 60 participants assigned to four experimental groups and 30 participants assigned to the control group. There were two experimental conditions, namely, experimentation with manipulation of real material, experimentation with virtual manipulation, as well as a condition of control (ie, traditional instruction with no virtual experimentation). Conceptual tests were administered to assess student’s comprehension before, during and after the application of the virtual laboratories. The analyzes revealed that even though the two experimental conditions promote the conceptualization and correct interpretations of the student’s physical concepts in the domain of electromagnetism better than in the control group as expected; we see that, the use of the virtual tool obtains a greater acceptance as this study shows.

1. Introduction

Recent works in the last ten years have raised how to improve virtual simulations of electromagnetic phenomena due to the increasing availability of computers today and their contribution to teaching processes. Research on the use of computer simulations has a long history [1]. In this article we investigate the state of the art in simulations for scientific education especially in the teaching of electromagnetic phenomena focusing on the ways in which virtual laboratories can be used to improve the traditional teaching of electromagnetic physics, student’s perceptions towards this type of tools and the ways in which they can be integrated into the educational support to promote learning processes, we determine the effects produced by these tools in the teaching process and the results of the learning, which currently represents a true emerging paradigm that disseminates education in diverse environments, where users find themselves in authentic learning contexts to face immersive experiences in order to achieve meaningful learning. The knowledge, understanding and conceptualization of physics by students is based in most cases on the perception and applicability of these physical phenomena. The content for the teaching of university electromagnetic physics, is
developed in an abstract manner which greatly reduces the development of cognitive skills and also reducing the ability of students to be interested in the study of this science. However, for the traditional teaching of electromagnetic physics, only certain experiments can be presented to the students in the laboratory, since the students can not access dynamically and intuitively by themselves to the real experiences, making them more dynamic and meaningful learning of the electric and magnetic phenomena. A learning environment with a computer simulation has the advantages that students can systematically explore hypothetical situations, interact with a simplified version of a process or system, change the time scale of events, practice tasks and solve problems in an environment realistic without stress. In addition to improving knowledge, the application of multimedia can make the content of teaching simple and intuitive, in order to inspire the enthusiasm of students, improving efficiency and the perception of learning [2, 3]. By integrating graphics, text, sound and images, multimedia software can not only reproduce or simulate various experiments and physical phenomena, but also simulate the physical process, present the physical laws in a more intuitive way, in order to increase the expression of the content of teaching, mobilizing students to participate in multimedia activities through multiple senses, improving the classroom environment, attracting the attention of students to better stimulate the interest of learning and contribute to clarify the physical ideas, processes and methods. The application of multimedia technology can provide to students a astonishing experience, clear and realistic material in the classroom, so that they can perceive complete, clear and imaginary physical phenomena that are difficult to observe or achieve, feel many scenes that are impossible in traditional teaching in the classroom, construction of a physical model with initiative. In addition, students can understand physical concepts, laws and theorems more easily; At the same time, teaching is easy and efficiency increases. [4, 5, 6]

The present study focuses on answering the following research questions: How can the traditional teaching of electromagnetic phenomena be improved by the application of computer simulations? How can computer simulations be better used to support learning processes and improve results? What perceptions do engineering students have about virtual laboratories as a pedagogical tool in the teaching of electromagnetic phenomena? These virtual laboratories of electromagnetism, with an adequate pedagogical approach, can help teachers who teach this subject to find new ways of teaching, help to improve the bad reputation of the subject, motivate students, increase their interest and perception and They feel more attracted by learning this wonderful science.

In this article, we present the advantages of virtual laboratories and their pedagogical potential, then we describe the details of the controlled design of the study and compare the data in a test and post-test for the experimental and control group to evaluate the understanding of the students of the physical concepts. We then evaluate the student’s perception of the simulations by applying a Likert type survey in both sections [7, 8, 9, 10, 11, 12]. We conclude by presenting some implications of this study.

2. Competences evaluated
In Natural Sciences, 3 competencies are evaluated that are aligned with what is proposed in the Basic Standards of Competencies in Natural Sciences, published by the Ministry of National Education of Colombia in 2006: comprehensive use of scientific knowledge, explanation of phenomena and inquiry. Each of these competences has their respective performance levels whose objective is to complement the numerical score awarded to the students of the exam. Likewise, they allow students to be grouped into 4 levels (1, 2, 3 and 4). Each level of performance includes a qualitative description of the skills and knowledge estimated to have been developed in each level. Our entrance test was designed with a total of 16 questions in which emphasis is placed on the issue of electromagnetism, based on problem situations, analysis of diagrams and graphs. The entrance test was applied to a total of 30 students from the experimental group
and 30 students to the control group in Fig. 1, the results are presented by group, in terms of percentages of successes and mistakes, so we can see in the results obtained in each group that presents a homogeneity in the percentages of successes and failures; Likewise, percentages can be seen with a low level of competence, 35% interpretive, 31% argumentative and 35% propositive in the experimental group, on the other hand 37% interpretive, 31% argumentative and 37% propositive of the control group, observing a high percentage of incorrect answers in both groups. According to the established analysis, the performance levels established by the Icfes and the MEN are assigned to students are at a low level of competencies, with which the students begin the corresponding intervention stage.

3. Application of virtual laboratories-pedagogical guide
This part began with the explanation of each competence, how to work the guide in their respective moments, insisting on developing group and individual activities properly from freedom and autonomy, considering activities so that they themselves promoted meaningful learning and They are motivated by cooperative work, it is pointed out that for the proposed competition, something creative and meaningful should be proposed that, like the other competencies of evidence learned in each subject that is developed.

It was observed that the students were very anxious to start the first didactic guide, where the accompaniment of the teacher became important, some did not understand the way to start or read the guide as well as to follow it neatly, however as they did it, it was observed Not only were they engaged in activities such as simulation management and didactic guidance, but also the complete order was observed in the laboratory room where these activities take place and the positive attitude that each group printed in the performance of the practice also benefiting the vast majority of students. This also allowed the class to become more enjoyable and most of the students noted that their learning and understanding of electromagnetic phenomena in the activities carried out and in the written tests presented improved significantly.

The opinion of the students was analyzed by using two fundamental methodologies (see results in Figs. 2 and 3): The interview and the questionnaire or attitude scale. In this investigation, a closed questionnaire was chosen, consisting of 16 items, with the aim of collecting opinions outside of the established questions, the items are written as affirmations in which it is necessary to indicate with a scale from 1 to 5, all response possibilities, from the most opposite (level 1) to the most favorable (level 5). 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 (0.94). The measure of reliability
Figure 2: (Color online) Analysis of perceptions of the students about the virtual laboratories of electromagnetism (questions from 1 to 8): 1. the laboratory activity was motivating, 2. The level of difficulty of the laboratory is adequate for my knowledge, 3. My participation in the development of the experience was clearly explained, 4. Being able to simulate experiments at different times and parameters increases my understanding of physical phenomena, 5. The description of the experiment was clear and precise, 6. I have reached the competencies proposed in the activity with a virtual experience, 7. The theoretical foundation of the laboratory guide was adequate to achieve the proposed competencies, 8. The problematizing question and the problem situation have been significant for learning.

Figure 3: (Color online) Analysis of perceptions of the students about the virtual laboratories of electromagnetism (questions from 9 to 16): 9. The time for the development of the experience is adequate, 10. I have obtained feedback for learning through discussions in the small and large group, 11. I think it is a good activity to develop team skills, 12. The quantitative value of the activity in the final grade is appropriate, 13. The level of interactivity with the simulator is adequate to develop the competences, 14. The design of the mask of the simulator is attractive (size, color, etc), 15. The design of the animations in the guide is attractive, 16. The design of the text documents is clear and easy to read (font size, color, data collection tables).

According to Fig. 4 for interpretive competence, 65% of the students in the experimental group are at a high level of performance, since in addition to describing and establishing relationships, they justified and explained situations with clarity and organization, with 35% of
the students are still at a low level that went from describing only information to establishing relationships confronting data, compared to the students of the control group who did not apply the simulators or the didactic guide which we can affirm that performance in competitions was very low. For the argumentative competence there is a trend of 44% of the students of the experimental group not only make predictions, but also raise claims interrelated ideas percentage that increased in relation to the initial stage placing them in a high performance level, 56% of Students achieve a remarkable level which is evidenced by stating statements and justifications through meaningful arguments. In the proposed competition although there is an increase of 67% of the students, to justify ideas in a critical and creative way in front of the virtual laboratories placing them in a high level of competencies and only 37% of the students only propose alternatives to a fact and they do not make proper use of their creativity by placing them in a low level of skills, they improved the aspect of creating, producing and proposing solutions to the problems of their daily lives, some works showed a lack of a critical and creative proposal, this competition is made more difficult in relationship with the others.

It should also be noted that the control group did not significantly improve their performance of the competencies since they did not have the didactic-pedagogical elements and the simulators that could motivate them and help develop their generic competencies.

![Figure 4: (Color online) Post-test design involving 60 participants assigned to four experimental groups and 30 participants assigned to the control group](image-url)

4. Conclusions

Today, Likert scale data used in our research has been used in many studies in educational and psychometric fields to understand the attitudes of individuals. This study was conducted with the aim of correctly understanding their perceptions regarding the use of virtual laboratories by using a Likert scale to analyze the issues, challenges and the reliability of questionary, to provide evidence that the components of the scale are sufficiently intercorrelated and that the grouped items measure the perception of the students in the Magdalena University. The results obtained indicate a high favorability, both in the opinion of the students about their experience of learning of electromagnetic phenomena, as well as in our own as teachers of this subject in the engineering students of the University of Magdalena, showing a more positive attitude and an improvement in the development of the competences and the final qualifications of their exams during the semester, results that are evidenced in the final stage, obtaining that the students have a greater apprehension about the actions and conceptualizations around the subject in study. It was also evident that the students presented difficulties to develop and work each of the generic competences through the virtual tool and the pedagogical didactic guide since it demanded a greater critical and creative value when dealing with the issues. It is important to note that
this form of work motivated students to be more committed when it comes to contributing positively to classes. The virtual simulations mediated with the didactic-pedagogical guides make a perfect binomial in that they facilitate the teaching and development of cognitive skills and also enhancing each of them, also favoring other types of competences.

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