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ВИКЛАДАННЯ КЛАСИЧНОЇ МЕХАНІКИ В ІБЕРО-АМЕРИКАНСЬКИХ ПРОГРАМАХ ПІДГОТОВКИ БАКАЛАВРІВ ІНЖЕНЕРНИХ СПЕЦІАЛЬНОСТЕЙ. СТАН ВИВЧЕННЯ ПРОБЛЕМИ

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АНОТАЦІЯ

Постановка проблеми. *Викладання природничих наук, зокрема фізики, зарекомендувало себе як обов'язковий орієнтир, особливо серед іберо-американських професіоналів. Отже, необхідно заглиблюватися в теоретичні основи досліджень і досліджень, сприяти обґрунтованим роздумам щодо стану та перспектив різних пріоритетних напрямків досліджень на даний момент, а також сприяти інтерпретаційній роботі, яка дозволяє просунутися в розуміння значущих проблем, пов'язаних із вивченням природничих наук.*

Матеріали і методи. *Методологічною основою дослідження був документально-бібліографічний аналіз, що полягав у зборі та подальшому відборі доречної інформації щодо предмету дослідження; аналітичне та всебічне вивчення текстів; вилучення одиниць аналізу з документального матеріалу, відповідних даних і залучення їх у процес перегляду, експертизи, опису та аналізу. Таким чином, були відібрані статті з таких індексованих журналів як то: Latin American Journal of Physics Education, The Physics Teacher, Journal of Research in Education, American Journal of Physics, British Journal of Educational Technology, Revista Enseñanza de las ciencias, Revista de Enseñanza de la Física, Acimed, Revista Científica, Revista Mexicana de Física, Revista Academia, Enseñanza de las Ciencias, Revista Española de Física, Revista Cubana de Química, Educacieón Cubana de Química, Educacieón Mexicana de Física, Educacieón Mexicana de Física, Revista Academia, Enseñanza de las Ciencias, Revista Española de Física, Revista Cubana de Química, Educacieón Cubana de Química, Educacieón de la Física, Educacieón Mexicana de Física, Educacieón de la Física, Educacieón de la Física, Educacieón de la Física Colombiana de Psiquiatría, ALTERIDAD Revista de Educación, Revista mexicana de investigación educativa, Didasc@lia: Didáctica y Educación, Multiciencias, Escenarios, Comunicar, Revista Academia y Virtualidad та інших.*

Результати. *У статті представлені результати науково-педагогічного дослідження, метою якого було шляхом вивчення праць іберо-американських дослідників, які опікуються проблемами викладання фундаментальних наук, зокрема фізики, на рівні вищої освіти, встановити, як вони оцінюють застосування в освітньому процесі дидактичних стратегій, опосередкованих інформаційно-комунікаційними технологіями; які результати дало використання таких методів навчання та чи сприяли вони покращенню результатів навчання студентів на заняттях з фізики (зокрема, класичної механіки) програм підготовки бакалаврів з інженерії.*

Висновки. *Автори виявили, що загалом іберо-американські вчені вважають сприятливим використання дидактичних стратегій, опосередкованих інформаційно-комунікаційними технологіями, оскільки вони окреслюють нову освітню динаміку, що дозволяє розширити та збагатити традиційну педагогіку новими навчальними*

CLASSICAL MECHANICS´ TEACHING IN IBERO-AMERICAN ENGINEERING BACHELOR'S DEGREE PROGRAMS. STATE OF KNOWLEDGE

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ABSTRACT

Problem formulation. *The teaching of science, in particular physics, has established itself as an obligatory point of reference, especially among Ibero-American professionals. Hence, it is necessary to delve into the theoretical basis of the studies and research, promote well-founded reflections in relation to the state and perspectives of the different priority lines of research at present, and promote interpretative work that allows us to advance in the understanding of significant problems related to science learning.*

Materials and Methods. *The research was carried out following the documentary-bibliographic method, which consisted of the collection and subsequent selection of pertinent information on the subject of the study; analytical and comprehensive reading of texts; extraction of the analysis units from the documentary material, the pertinent data, and its submission to a process of review, examination, description, analysis. Thus, the articles of the following high-impact journals were selected: Latin American Journal of Physics Education, The Physics Teacher, Journal of Research in Education, American Journal of Physics, British Journal of Educational Technology, Revista Enseñanza de las ciencias, Revista de Enseñanza de la Física, Acimed, Revista Científica, Revista Mexicana de Física, Revista Academia, Enseñanza de las Ciencias, Revista Española de Física, Revista Cubana de Química, Educación Médica Superior, Revista Estilos de Aprendizaje, Revista electrónica Actualidades Investigativas en Educación, Revista Colombiana de Psiquiatría, ALTERIDAD Revista de Educación, Revista mexicana de investigación educativa, Didasc@lia: Didáctica y Educación, Multiciencias, Escenarios, Comunicar, Revista Academia y Virtualidad, Tarbiya, among others.*

Results. *This paper presents the results of scientific-pedagogical research, which goal was to establish by studying the works of Ibero-American researchers who address the problem of basic sciences´ teaching, in particular, physics, at a higher level, how the use of didactic strategies mediated by Information and Communication Technologies applied to physics courses, is visualized; what results has it given and if it helped to improve the students learning results in engineering bachelor's degree programs.*

Conclusions. *The authors found that scholars conceive the use of ICT as favorable since they outline new educational dynamics that allow extending and enriching traditional pedagogy with new learning resources; they foster alternative forms of communication; they solve the problem of physical space; they attenuate the autonomy of the student; they favor the collaborative mode of learning; enhance motivation and improve student learning. However, in this process the prior training of the teacher in the use of ICT becomes important.*

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ресурсами; вони сприяють альтернативним формам спілкування; вирішують проблему фізичного простору; стимулюють розвиток автономії студента у процесі навчання; віддають перевагу роботі у групах; підвищують мотивацію та покращують успіхи студентів у засвоєнні нових знань. Однак у цьому процесі важливою стає попередня підготовка викладача у використанні інформаційно-комунікаційних технологій у навчальному процесі.

КЛЮЧОВІ СЛОВА: *іберо-американські програми підготовки бакалаврів з інженерії; викладання фізики, зокрема класичної механіки; дидактичні стратегії, опосередковані інформаційно-комунікаційними технологіями, що застосовуються на заняттях з фізики; наукові здобутки іберо-американського науково-педагогічного простору.*

KEYWORDS: *Ibero-American engineering bachelor's degree programs; teaching of physics, particularly classical mechanics; didactic strategies mediated by information and communication technologies applied to physics courses; state of knowledge in the Ibero-American pedagogical scientific space.*

INTRODUCTION

The teaching of science, in particular physics, has established itself as an obligatory point of reference, especially among Ibero-American professionals. Hence, it is necessary to delve into the theoretical basis of the studies and research, promote well-founded reflections in relation to the state and perspectives of the different priority lines of research at present, and promote interpretative work that allows us to advance in the understanding of significant problems related to science learning. In this sense, it is important to analyze the studies that correspond to the needs of science teachers, particularly physics teachers, and to know the impact of different educational practices at different levels.

Learning physics at various educational levels, from secondary, pre-university and university, is a difficult process for a considerable number of students in any educational institution. One of the topics in physics, classical mechanics, is always included in a first physics course in Ibero-American engineering bachelor's degree programs. Physics is an indispensable prerequisite for the study of engineering, since it explains and predicts physical phenomena, thus establishing the foundations of its engineering applications (Beltrán, 2021).

The main purpose of learning classical mechanics in Ibero-American engineering bachelor's degree programs, is to develop in the student the ability to analyze any mechanical situation presented in a logical and simple way, applying well-assimilated basic principles in its resolution. Therefore, the learning of mechanics is oriented towards the understanding and application of its fundamental principles. In an engineering bachelor's degree program, the methodology and contents of the subject "Classical Mechanics" are considered from the perspective of the engineer, that is, as an applied science.

Researchers who address the problem of classical mechanics´ teaching at a higher level (Aguilera-Pupo & Ortiz-Torres, 2009; Amaya, 2008; Bandiera et al., 1995; Bayrak, 2008; Black et al., 1997; Catalán et al., 2010; Celemín & Covián, 2003; Cobas-Abad et al., 2017; Debel et al., 2009; García et al., 2003; Gómez-Mercado & Oyola-Mayoral, 2012; Guisasola et al., 2003; Gil & De-Guzmán, 1993; Jaque, 1995; Maloney, 1994; Mora & Herrera, 2009; Murga-Menoyo et al., 2011; Pedraza & Sánchez, 2011; Salinas et al., 1996; Solbes et al, 1994, Velázquez-Revilla et al., 2018; among others), consider that to achieve the fundamental goal of a mechanics course, it is necessary to focus attention on interpreting results and not so much on the mathematical part (García et al., 2003); encourage practical work (Celemín & Covián, 2003); avoid solving stereotyped problems only by applying mathematical formulas; recognize the particular characteristics of the students: way of learning, previous ideas, ways of reasoning, interests and attitudes; and consider the context of what is taught and its relationships to other disciplines (Solbes et al., 1994).

Likewise, they affirm that when learning is difficult, it is attributed to different factors:

– Lack of understanding of concepts that are a prerequisite for a first university course in this science;
– The conflict between common sense knowledge and scientific knowledge;
– Poor preparation in mathematics;
– The complexity of the conceptual structure of physics;
– The use of inappropriate teaching materials;
– The insufficiencies of the proposed learning environments, among others (Jaque, 1995).

The authors find the following formative insufficiencies of the student in classical mechanics:

– Long-term comprehension and learning problems (Bandiera et al., 1995; Salinas et al., 1996);
– Erroneous preconceptions (Mora & Herrera, 2009; Pedraza & Sánchez, 2011);
– Inappropriate study strategies to solve problems (Maloney, 1994; Guisasola et al., 2003);
– Application of solutions learned by heart, without considering their relevance (Gil & De-Guzmán, 1993).

Unfortunately, in most engineering bachelor´s degree programs, classical mechanics is taught in a traditional way, which does not allow solving the aforementioned problems. However, many of these difficulties could be deciphered from a didactic approach that promotes making predictions, experimenting, comparing and interpreting results (Beltrán, 2021). Hereafter, scholars suggest modifications in the strategies used to motivate the student and obtain significant learning. In this sense, Information and Communication Technologies (ICT) have been shown to be effective in teaching and learning classical mechanics (Bayrak, 2008; Debel et al., 2009; Catalán et al., 2010; among others).

THE PURPOSE OF THE ARTICLE

The objective of this research was to establish, through a documentary-bibliographical study of the works of Ibero-American researchers who address the problem of basic sciences teaching at a higher level, in particular, of physics, how the use of didactic strategies mediated by Information and Communication Technologies applied to physics courses, what results have they given and if they have helped to improve student learning in engineering bachelor's degree programs.

METHODS OF THE RESEARCH

The research was carried out following the documentary-bibliographic method, which consisted of the collection and subsequent selection of pertinent information on the subject of the study; analytical and comprehensive reading of texts; extraction of the analysis units from the documentary material, the pertinent data and its submission to a process of review, examination, description, analysis. This method allowed to study and interpret the selected bibliography; distinguish the fundamental points and systematize the information; classify frames of reference, concepts, establish convergences and divergences; face the results and opinions; generalize and extract relevant data for the inquiry.

Thus, the articles of the following high-impact journals were selected: *Latin American Journal of Physics Education, The Physics Teacher*, *Journal of Research in Education, American Journal of Physics, British Journal of Educational Technology, Revista Enseñanza de las ciencias, Revista de Enseñanza de la Física, Acimed, Revista Científica, Revista Mexicana de Física, Revista Academia, Enseñanza de las Ciencias, Revista Española de Física, Revista Cubana de Química, Educación Médica Superior, Revista Estilos de Aprendizaje, Revista electrónica Actualidades Investigativas en Educación, Revista Colombiana de Psiquiatría, ALTERIDAD Revista de Educación, Revista mexicana de investigación educativa, Didasc@lia: Didáctica y Educación, Multiciencias, Escenarios, Comunicar, Revista Academia y Virtualidad, Tarbiya,* among others.

The documents and materials of the following academic events were reviewed: *Second International Conference on Concept Mapping,.* San José, Costa Rica; *Congress "Psychology of knowledge applied to school work"; The XI Congress of Educational Innovation in Technical Education; The International Meeting on Meaningful Learning,* Burgos, Spain; *The International Conference on Engineering Education,* Valencia, Spain, among others. Likewise, this research is supported by the theoretical works of the teaching of basic sciences, in particular, of physics, of Young, Freedman, Moreira, Maloney, Hierrezuelo, Montero, Hamne, Bernhard, Hernández-Rojas, Díaz-Barriga, Hernández, among others. Master´s and doctoral theses were also analyzed.

RESULTS OF RESEARCH

The results of the documentary-bibliographic research carried out, reveal the following. In the first place, the studies of Ibero-American researchers related to the topic of didactic strategies mediated by ICT applied to basic science courses, such as physics, chemistry or mathematics (Bassani, 2009; Gómez-Mercado & Oyola-Mayoral, 2012; Rodríguez et al., 2014; among others), in general show that these types of strategies have a positive impact on academic improvement in students, increasing their motivation and interest in these subjects.

Therefore, Bassani (2009) from the National University of Salta, Argentina, in his work "Blended teaching strategies mediated by information and communication technologies", presents the results of the application of combined teaching strategies, that is, of way different from the traditional one, using technological mediation. In this study, three basic categories were analyzed: university education, the blended modality and the application of New Information and Communication Technologies (NICT). The objective of this research was to assess how the incorporation of NICT influences teaching and learning in blended media in university education to obtain a degree and to identify the most relevant characteristics of a pedagogical nature in learning through multivariate strategies. Some of the conclusions of this work were the following (Bassani, 2009):

– The incorporation of NICT in the blended modality of university degree course was accepted by teachers and students.

– The teacher-student relationship began with some fear, but was transformed into curiosity before the understanding of technology.

– There was a positive increase in motivation among teachers, when using NICT.

– By applying multivariate strategies in such a modality, it favored large groups.

– The students took advantage of the teaching website in the external search for data, especially those who work or live far from the university.

– From the perspective of those who are actors, the advantages achieved are greater, since autonomy, good interaction and ease of learning were achieved.

– An important disadvantage was the lack of previous student training to use technology tools and the Internet.

This experience was an essential advance that made it possible to visualize future educational changes and promote a difference between face-to-face and distance work.

On the other hand, Yanitelli (2011) from the University of Burgos, Spain, tries to define the scope and perspectives of incorporating the computer to teach physics, since this enables university practices in basic physics and gives more importance to the reflection about the experiment, the interpretation of results, as well as obtaining conclusions. It was also reviewed how students build concrete knowledge at the mental level, the ideas displayed, the levels of representation and abstraction reached and the specific cognitive skills they use when solving experiments through a computer system to acquire data in real time.

The author considered the contributions of Ausubel´s Significant Learning, Johnson-Laird´s Mental Models and Vygotsky´s Mediation as theoretical references. The study allowed us to glimpse the specific cognitive abilities in their development associated with an appropriate selection of sensors, interactive communication in the representation of data, the statistical elements used and the explicit analysis of the evolution of the graphs recorded with the computer.

The results provided the conclusion that the real-time data acquisition and processing system helped students make decisions in the experiments, in the recording and data processing phases; they could contrast the properties of the conceptual model with those of the studied system; they develop specific cognitive skills and have a critical stance when analyzing the experimental situation (Yanitelli, 2011).

As mentioned above, most of the analyzed researches mention the benefits of applying ICT in the teaching framework, however, Gutiérrez-Mendoza, Ariza-Nieves, Jaramillo (2014) from the University of New Granada, Spain, believe that teacher training in the use of ICT is also of the utmost importance. It is about the preparation in teaching methodology and design of

didactic strategies mediated by ICT, as well as the need to strengthen basic concepts by students, required to take physics course (Gutiérrez-Mendoza et al., 2014).

In short, since the end of the 20th century - the first two decades of the 21st century, there has been extensive research about the use of didactic strategies mediated by Information and Communication Technologies applied to physics courses, likewise, this topic was of great interest to scholars in the times of COVID19 when most of higher education became online. And until now it is still current. Nevertheless, the physics education theme has always been present, since many problems of understanding in physics have constantly been frequent in students. Therefore, there have developed various proposals on the efficient use of didactic methods applied to teaching physics. In the works of the Ibero-American researchers, the following examples are found:

– Instructional planning considering student preferences regarding learning practices, proposed by professor Ramírez, professor at the Center for Research in Applied Science and Advanced Technology of the National Polytechnic Institute of Mexico (Ramírez, 2010);

– Application of interactive methods, favoring student participation with the teacher´s guidance, to achieve the purposes of the course, such as Problem Solving Learning (PSL), Project-Based Learning (PBL), or the TADIR protocol, created by professor Barojas of the National Autonomous University of Mexico (UNAM) (Barojas, 2007);

– Support for the development of metacognitive practices, a proposal by professor Soto from the University of Bogotá, Colombia (Soto, 2002);

– Implementation of the experiments in real time projected by Redish, Saul, Steinberg (1997); Thornton, Sokoloff (1998); Hamne, Bernhard (2001), that promotes a good conceptual understanding in mechanics, according to the opinion of professors Catalán, Serrano and Concari of the Faculty of Sciences Applied to Industry of the National University of Cuyo, Mendoza, Argentina (Catalán et al., 2010).

Several studies (Amaya, 2008; Bayrak, 2008; Debel et al., 2009; Catalán et al., 2010; Guerra et al., 2010) have demonstrated the effectiveness of these tools at various levels of education, from secondary education to university.

At the same time, he study carried out revealed that within the physics teaching area, there are numerous works that provide empirical evidence on the incidence of the use of strategies mediated with ICT to teach this science. For example, the use of virtual laboratory or simulation software at different educational levels (Amaya, 2008; Bayrak, 2008).

Among the benefits of using technology in the educational process are (Condie, Livingston, 2007; Mouza, 2008): access to materials; increased motivation and productivity; improvements in understanding and performance of the students. The interactivity of technologies is another feature that is mentioned, and that allows students to receive feedback, test and reflect on their ideas, and analyze their understanding (Bransford et al., 2000). However, the presumed benefits of ICT mentioned come to be isolated pedagogical innovations in their school context and in the culture of the discipline of educational institutions and systems.

The documentary-bibliographical analysis carried out showed that there are also several studies related to the use of concept maps in teaching. Duarte and Henao-Cálad (2006), participants in the Second International Conference on Concept Maps held in San José, Costa Rica, made a classroom proposal mediated by concept maps in order to show this network of relationships as a manifestation students´ understanding of the concept to be studied.

These researchers are based on Ausubel´s Teaching for Comprehension and Meaningful Learning approach and use concept maps as tools for exploring and structuring knowledge. The conclusion of their work is that the application of the aforementioned approaches and tools allows students to be more motivated to carry out learning activities and to be more responsible in the construction of their own knowledge. Similarly, the importance of leaving records of internal processes and concrete manifestations in each of the stages of the personal construction of knowledge in a portfolio of activities is mentioned.

The benefits of using concept maps to achieve meaningful learning of concepts are stated in several works by Cuban researchers (Ojeda-Cabrera et al., 2007; Vidal-Ledo et al., 2007). These are tools for association, interrelation, discrimination, description and exemplification of content with great visualization power, which allow organizing and expressing ideas, understanding concepts, deepening, processing, organizing models and prioritizing information. The concept map is used in the teaching-learning process to help students obtain deeper knowledge when searching for meaning, to promote “learning to learn” and to facilitate collaborative work.

A study carried out by Murga-Menoyo, Bautista-Cerro and Novo (2011) of the National University of Distance Education (UNED) of Spain entitled “Concept maps with CmapTools in university teaching of environmental education: case study at UNED”, presents an experience in teaching with the use of the CmapTools. The conclusions of the research work were the confirmation of the relevance of the conceptual mapping technique for the objectives of the subject, and the motivating capacity of educational technologies and software, as well as active and participatory learning activities, was affirmed. It is verified in this study that the elaboration of the concept maps with CmapTools requires small groups of students to take full advantage of what the educational software offers.

The work of Velázquez-Revilla, Revilla-Puentes and Guerra-Ortizes (2018) from the University of Havana, Cuba, analyzes the use of concept maps in order to teach the concepts of organic chemistry at the university level. The researchers observed the difficulty of the students to generalize, integrate and apply concepts and laws of Organic Chemistry, hence they proposed to create conceptual maps on the fundamental concepts of this science that were used in lectures and practical classes.

The authors concluded that development of concept maps by students and teachers turned out to be a practical way to understand and generalize knowledge, articulate the contents of Organic Chemistry with others subjects in the study plan, acquire the ability to solve integrative problems and have greater motivation. The researchers found an improvement in the results of students and teachers, so they concluded that concept maps contribute to the integration of knowledge, the self-preparation of students and the achievement of meaningful learning (Velázquez-Revilla et al., 2018).

Regarding the teaching of physics in engineering bachelor’s degree programs, the study carried out by Cobas-Abad, Repilado-Ramírez and Gracia-Vega (2017) from the University of Las Tunas, Cuba, reveals the results of the application of concept

maps in the teaching of this discipline with geological engineering students. In this case, it was observed that the students had little motivation to meet the required learning objectives. The proposal of the work was to elaborate conceptual maps of a topic of the matter as a methodology to build the knowledge of physics and develop an active learning.

In conclusion, the article states that the teaching results in traditional physics courses, where methods such as theoretical classes, problem classes and laboratory classes are used, are not the desired ones. A large part of school dropouts occurs mainly due to low grades in physics and mathematics, which is why it is considered convenient to appropriate the basic contents to be able to solve problems and carry out experimental work. Concept maps can help establish the theoretical concepts that will be used later in other academic activities and, therefore, are recommended as a cognitive diagnostic tool (Cobas-Abad et al., 2017).

CONCLUSIONS AND PERSPECTIVES FOR A FURTHER RESEARCH

In summary, the results of the documentary-bibliographic study carried out show that Ibero-American scientists involved in the problem of teaching basic sciences, in particular physics, find the use of ICT profitable in the framework of higher education, including engineering bachelor´s degree programs. In general, the state of knowledge in the Ibero-American scientific-pedagogical space confirms that teaching strategies mediated by Information and Communication Technologies applied to physics courses, is one of the priority lines of Ibero-American research today.

Therefore, the studies reveal that ICT propose new methods that change the world of teaching, since teachers agree to be able to expand and complement traditional activities with new learning resources. These technologies facilitate the development of electronic teaching materials, promote alternative forms of communication, as well as favor the collaborative mode of learning, contributing to the accentuation of motivation and progress in student learning. The importance of the use of ICT to raise the responsibility of students in the construction of their own knowledge is also underlined.

Ibero-American researchers show that for the activities of a physics class, simulation mechanisms and virtual work laboratories can be found on the Internet to solve the problem of physical space, materials and equipment needed in a traditional laboratory; recreation and intervention in the natural when it is impossible to reproduce it in a face-to-face laboratory; promote the autonomy of the student to learn and, also, encourage new ways of learning that stimulate and motivate them. They also find mandatory prior teacher training in the use of ICT. Several research works related to the use of ICT in physics teaching are dedicated to concept maps, in particular, made with CmapTools.

Thus, the results of numerous investigations dedicated to the implementation of e-learning in physics courses at the higher level, show that by using concept maps, significant advances are obtained in the process of knowledge acquisition by students. This didactic tool allows to establish relations between the concepts in an explicit way and to refer the concepts based on new information with the knowledge previously acquired by the student. In the process of creating concept maps, the student learns to organize himself, to make decisions about the importance of ideas and concepts, to discriminate information; raises his motivation; becomes more responsible for the construction of his own knowledge; becomes more autonomous in his learning.

Regarding the prospects for future research in the area of teaching basic sciences, particularly physics at the higher level, we consider pertinent to address the issue of prior teacher preparation in the use of ICT, in particular, on the training for the use of CmapTools.

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