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SCIENCE TEACHING AND LEARNING WITH THE SUPPORT OF DIGITAL EDUCATIONAL RESOURCES UNDER A CONNECTIVIST APPROACH

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Abstract

The objective was to design a didactic experience to facilitate the teaching and learning processes of Physics (Kinematics) in students of a public university through ICT under a connectivist approach. It corresponds to a qualitative approach under an action research method. The research was carried out in a context with a group of 28 students enrolled in a Bachelor's degree program in Natural Sciences at a public university. According to the results, the presence of the teacher presents little interaction, since students control their own learning. In fact, the connective teaching strategy of kinematics showed that the teacher, far from controlling and mediating the teaching-learning process through ICT, must ensure that students create their own connectivity network for lifelong learning.

Keywords: learning, connectivism, education, physics, technology.

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1. Introduction

The teaching and learning process have been equipped with computers and measuring devices to recreate animations and simulations, so that it is the student himself who manipulates the experimentation system and the computer [1; Rodríguez Ibáñez, 2018]. Therefore, the teaching and learning of Physics requires a change in the transmissive model taught in university classes [2; Hernández Suárez et al., 2021; Avendaño-Castro et al., 2021; Hernández Suárez et al., 2021]. It responds to the needs of a new social and technological context that has a natural space in the Internet [3]. In addition, higher education seeks to train people who are highly prepared to adapt to the changes resulting from technological evolutions in the field of science.

ICT provides the appropriate means for the educator to foster higher order thinking in students, a key element of 21st century skills [4, Prada Núñez et al., 2020], through carefully structured activities [5]. Moreover, being able to adapt to the needs and demands of each student to favor autonomy [6].

Thus, in a networked world, mediation in different virtual environments is essential [7], which allow various forms of interaction between the actors of the didactic act from the management of educational practice in multiple zones of possibilities [8]. However, students are often unmotivated to assimilate this science, they do not only need to see the contents, to develop their logical and abstract thinking with the use of technological tools [8]. For this reason, research on the use of current technological tools has been oriented [9]. The blended learning modality in a course for the Physics I subject [10]. Similarly, the management of tasks and communication tools between students and teachers in a virtual platform [11]. Likewise, as a pedagogical strategy for the development of the competence comprehensive use of scientific knowledge in the teaching of Natural Sciences [12], in the management of ICT for learning Physics [2], apart from being a support tool in experimental activities in Physics [13]. As well as a didactic tool to integrate ICT in Physics teaching [14].

On the other hand, ICT in the teaching-learning process is directed towards the cognitive domain in science in initial training through the Technological Pedagogical Knowledge of Content [15]. For example, in the study of kinematics, it is common to take students to the laboratory where they measure different properties of motion that they then plot in graphs. Then in class, they analyze the results and perform calculations to obtain the values of velocity and acceleration. However, it seems that students often perform these operations without a real understanding of what they are doing [1]. It seems that it is being forgotten that pedagogy and curriculum are elements of learning that are expanded with technology, which constitute three essential elements for an educational transaction: cognitive presence, social presence and teaching presence [16]. Thus, connections arise between the understanding of content, pedagogy and technology by educational actors, leading to strategies of

exploration and social experimentation, since learning is a social phenomenon. The connectivist theory recognizes in learning an applicable knowledge, outside the individual that links specialized information with other connections to increase it, all thanks to the development of the critical ability to make decisions [35].

Hence, the idea of deepening the teaching-learning process under connectivism [17], specifically in the area of Physics in higher education through Information and Communication Technologies (ICT), which aims to deepen knowledge from practice through technological means such as simulators, a purpose currently pursued by Latin American educational institutions and that governments such as that of Colombia are trying to include within the pedagogical processes in higher education through investment in research [34].

In practice, learning in the 21st century demands the incorporation of ICT and the development of basic cognitive skills through connections in the personal learning environment as a space that promotes personal learning networks [18] under a connectivist approach [19], relevant to an information and knowledge society where students associate connections [19]. The objective of this research was to design a didactic experience to facilitate the teaching and learning processes of Physics (Kinematics) in students of a public university through information and communication technologies [ICT], under a connectivist approach.

2. Theoretical framework

Studying kinematics involves the study of mainly rectilinear motion at constant velocity in order to discover the fundamental laws of classical mechanics (law of inertia). Therefore, an understanding of the concept of velocity, displacement and the time interval must be provided. The teaching of Kinematics, is often approached as an activity to "fulfill the conditions to regularize the subject", in a routine environment and with a "recipe approach" [1]. This kind of structure either in lectures or science laboratory respond to a certain conception of teaching [20], which leads teachers to prefer practical work that allows students towards the correct answer. Therefore, the teaching and learning process, as well as the didactic experience that involves the mediation of three elements such as: student, teacher and the didactic medium [19]. Thus, the teacher sets the guidelines in its design, with the purpose of achieving the learning objectives. Although Information and Communication Technologies (ICT) are incorporated in these experiences, they require the construction of an educational and, strictly speaking, didactic use of these technologies [21].

To overcome these difficulties, and thus facilitate an inquiry into the concepts of kinematic phenomena, the use of technology facilitates the quality of the data collected on the phenomena, while

supporting the student in the process. Thus, teacher, students, resources and activities converge in a natural or virtual ecosystem, according to what is planned in teaching, learning and evaluating [22]. The new educational trends suggest that the thinking of the learning subject acquires an outstanding value in the joint actions, entangled between human beings and technologies, i.e., between network and actors [23]. Therefore, it is necessary for science students (Physics) to make their previous ideas explicit, but at the same time they require a constant adaptation of the subject's schemas to the world in which he/she develops, which expressly alludes to the need of a previous external mediation (digital culture, collective intelligence) that is supported through ICT; which, obviously, sustains the development of socially mediated processes with ICT.

From a connectivism perspective, all knowledge is constructed by the constant interaction between subjects, as well as learning objects, Siemens assumes that the creation of meanings and relationships occurs through connective processes in the formation of new knowledge ecologies and learning cultures [19], in which, knowledge rests in networks, as it resides in human and non-human devices; and, learning is enabled/facilitated by technology, it also says that learning is a process of connecting specialized nodes or sources of information.

This emphasizes the freedom of choice to use different ICT systems and tools that meet personal learning needs. This suggests having a personal learning environment (PLE) to develop the didactic experience, where the learner is connected to other people's PLEs. In practical implementation under connectivism, learning is learner-centered [24]. This approach is based on principles of active learning for networks. In addition, it suggests three key aspects: they should be holistic, adaptive, and outcome-focused [25].

First, holistic refers to representing the situation in a diverse way, allowing multiple perspectives and points of view. It is inferred that holistic vision means encountering various subspaces, formed by many individuals trying to realize their personal goals. That is, it allows individuals in communities to share similar views or form networks. In which knowledge can be interpreted and translated, creating new knowledge. Second, they must be adaptive, in other words, able to adapt and change as the environment changes. Thus, the activities of the community influence, through feedback and is interpreted as knowledge, which intervenes not only in this community, but also in other communities.

Hence, connected learning allows an opportunity from collective networked intelligence and experiences with other individuals [26]. Similar premise to social constructivism, which proposes an essentially exogenous development process, in which cognitive functions emerge through social mediation due to the fact that: “In cultural development...it appears twice: first, at the social level, and later, at the individual level” [27], therefore, it is inferred that social interactions become the

activation of mechanisms for connective learning. Thirdly, the desired objectives would be the desired results that could be obtained in the process. It is inferred that they would achieve with a new meaning of knowledge according to the mutual interrelationships between individuals, their goals, what they see and use in the surrounding system. This knowledge is not only taken from the content, but also with certain tools, artifacts or people. Thus, communities always shape their spaces and spaces shape communities. In this sense, it requires dynamism, distribution and a semantic condition, which contains four elements: autonomy, diversity, openness and connectivity [24].

a) Autotomy, refers to the environment where they learn independently and choose among resources, connections and information through ICT; it is considered to be self-directed learning.

b) Diversity, represents the opinions of the connections and emerging from the social context in learning networks using technologies for this purpose.

c) Openness, it contemplates resources and information in different formats (text, audio, video, etc.) for example in the personal learning environment; that is, it opens a cognitive presence.

d) Connectivity, comprises the networked social connections necessary to facilitate learning. This results in the establishment of a network of connectivity between network-actors, as well as connectivity between "social presence" in a formal educational environment that could be extended to an informal networked context, as well as "cognitive presence" [16], which ensures a certain level of depth in the educational process, and "teacher presence". In connectivist-based learning, the teacher would not necessarily be present, but it could be argued that mediation of that teacher role is necessary to some extent.

All of the above, leads to articulate fundamental aspects that respond to the needs of the teaching and learning process with ICT [28], such as: **(a) Flexibility,** of students and teacher in the use of digital material and adapt to new needs to perform a particular task; (**b) Versatility,** with digital tools to perform different tasks or activities in different formats; **(c) Interactivity**, with the use of digital tools to interact and discover a series of contents that facilitate their achievement in the accomplishment of tasks; and, (**d) Relationships,** to communicate, share and exchange information through the use of social networks or virtual platforms.

In summary, the development of didactic experiences under a connectivist approach could promote ways of perceiving, reasoning and interpreting the world of kinematics by connecting ideas or opinions in the diversity of collective intelligence in the network, different from those proposed in traditional teaching, Moreover, ICT and the connective approach promote active work, as well as collaborative and cooperative work, enhance interpersonal skills and autonomy as well as ease to perform different tasks at the same time [29], also with ICT the ability to appropriate visual stimuli at high speed that could be supported in instructional models [30].

3. Methodology

The research corresponds to a qualitative approach under an action-research method (Gamboa, 2019), since it implies a new vision of man and science, more than a process with different techniques, which has a practical interest, in the interaction with other human beings [31]. It is important to highlight that the research seeks to make a study where observations, comprehensions and conceptualizations are achieved based on the individualities, interactions, dynamics and productions of the participants, in order to analyze the contribution of ICT under a connectivist approach to the teaching-learning process of Physics (Kinematics), by introducing improvements or generating change [32]. Therefore, the work was done in a context with a group of 28 students enrolled in a Bachelor's degree program in Natural Sciences at a public university.

Similarly, a quantitative analysis of the information provided by Scopus is proposed under a bibliometric approach on the scientific production related to Teaching and Learning in Higher Education through ICT identified from Latin American institutions in order to know the approach of scientific papers through the use of keywords. The aim is to know the impact and scope of the research published under the aforementioned topic thanks to the map of co-occurrence of words, which allows locating the current context of the research carried out as a complement to the development of the new methodologies proposed in this article.

Collection of information

For the proposed biometric analysis, a search is performed in the Scopus database. For this purpose, filters are established to identify the publications most related to the topic of study of this document. the selection of articles or research papers is done by establishing search criteria:

Research papers (articles, conference papers, books, book chapters, among others) whose variable of study is Teaching and Learning of Physics in Higher Education through ICT

Categories of analysis

The following are the initial categories according to the problem and the research objectives.

Table 1. *Categories*

Categories	**Definition**
Connectivity	Seeks to establish human and non-human connections for self-directed networked learning.
Diversity	Collective knowledge in the social context in learning networks using technologies
Connective teaching strategy for kinematics.	Process through which the construction of new knowledge is promoted by the student, establishing diverse connections with autonomy and open resources.
understanding kinematics	Key practice involving the study of mainly rectilinear motion at constant velocity.

4. Procedure

The procedure proposed by [33] was used, where an action was planned, the action was executed, observed and reflected on what happened. Therefore, the phases are detailed:

Planning phase

A didactic strategy was designed through ICT based on connectivism [19] for the understanding of Kinematics, at the beginning of the first semester of 2019, under a blended learning modality. The following work method was carried out: (a) the experience is designed under the rules and curriculum of the UFPS; (b) in the face-to-face context, the activities were carried out in a Physics laboratory, where they could execute the experiments of movements of the balls under the mediation of the teacher with 2hr of duration; c) in the digital context, an implemented pedagogical proposal was designed that includes the objectives of the activities, content structure of the studied area, the paths followed to achieve its objectives, taking into account a zone of possibilities [8] to learn and perform the activities offered through a virtual classroom, with openness [24] to sites, places and people in the network concerning the field of Physics (Kinematics), so that the student was creating connections in a personal learning environment with autonomy, self-directed, flexible and interactive and develop a better understanding of the concepts of time, distance and speed, i.e. understanding of kinematic phenomena that require the assimilation of concepts.

Execution and observation phase

In the action setting, each student recorded their assignments, activities and achievements in their practices on the understanding of kinematics, creating connections to their interests and motivations. As for observation, learning analytics is performed on these records, activities and achievements of the students. At this point, Martínez points out that in action research there is no single type of search and information gathering techniques [31]. Hence, a notebook was used to record observations on the course of events, critical details, introduction of the approach by the teacher, the teacher's statements as well as studying the learning process of the students, analyzing the openness of the contents, information and activities that the students had to complete. At the same time, this notebook was used to register the written, verbal and iconic responses when making drawings of the object in motion, and position or velocity graphs as a function of time, as well as learning analytics in the online context about connections, sites and places.

5. Reflection phase

This phase of analysis made it possible to relate theory and practice between action and reflection. It was appreciated that the facilitated experience contains a zone of possibilities towards a diversity of resources and points of view that makes the network connected, rich and dynamic, because, it gives openness to network sites and people that make possible the understanding of kinematics; therefore, it was a meaningful experience.

In relation to the above, it was pointed out that the intended learning approach promoted a context in connectivist students to find and transform information into knowledge; however, they needed an adaptation process to be able to process, classify, evaluate, interconnect and evolve, according to a wider didactic space to the domain of the virtual learning environment. This diversity (formal and informal) gives rise to the co-construction of knowledge, beyond the single source to develop their skills and knowledge in kinematics. Excerpts from the interactions of the research subjects are presented below.

Student 3: The activities helped to understand the different aspects of rectilinear motion at constant speed. Understanding velocity depends on formulating and identifying the factors of velocity. These two factors are necessary to understand velocity.

Student 6: ...distance traveled during a certain time Student.

Student 9: ...distance traveled in proportion to time elapsed.

Student 11: ...quotient of the distance traveled and the time elapsed.

As can be observed, the student can use different ways of formulating and identifying the factors instead of the formulation correctly imposed by the teacher, since in the diversity of opinions and collective knowledge they express it in the form of correspondence (student 6), as well as proportion (student 9) or quotient (student 11). With this, it follows that the self-directed learner is nurtured by a personal learning environment under the mediations of cognitive presence [16], in which interactivity is established with digital tools [28] and social connectivity in the network with other people [24] for the identification and understanding of speed factors and, therefore, actively connected to the network [19], which responds to the category of analysis connective teaching strategy, since it promoted the construction of new knowledge in various human and non-human connections with autonomy, versatility and flexibility.

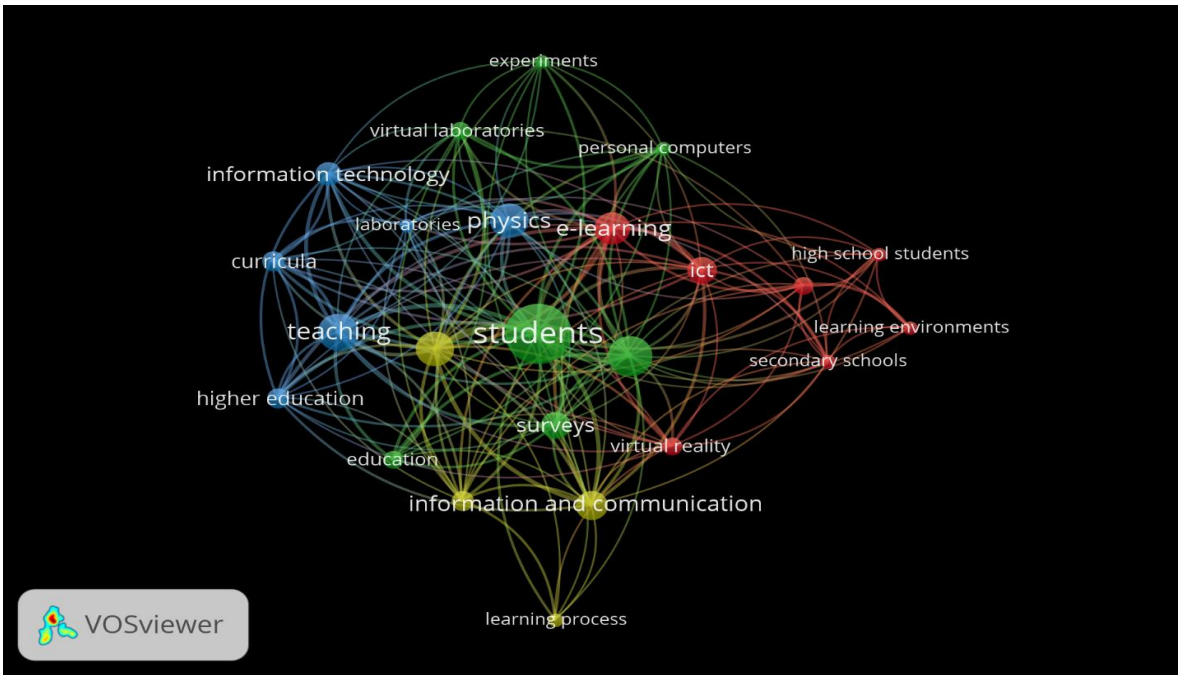
6. Results and discussion

Bibliometric analysis

Keyword Co-occurrence Map

Figure 1 shows the interaction between the different study variables used in the research identified through the Scopus database. Thus, the word Students was the most frequently used, focusing the research on topics related to Virtual Reality, Teaching, Learning, Physics, Online Learning, Teaching, and Higher Education, which confirms the relevance of the papers identified with the topic of study proposed in this paper. It is important to highlight that the teaching and learning processes based on the use of ICT, specifically in the area of Physics, are framed in a large number of utilities within which are the simulation in the study of the different topics addressed in the theories of physics at the higher education level, as well as the solution of problems by means of digital tools supported in artificial intelligence as a strategy designed from the innovation derived from great efforts in research, hence the importance of knowing the current state of the bibliography published under the topic mentioned above, as bases theories for the construction of innovative tools in support to the teaching of Physics in higher education.

Figure 1. *Co-occurrence of words*



Source: Own elaboration (2021); based on data provided by Scopus.

A good example of the above is the article entitled "*Teaching Physics in higher education: Use of information and communication technologies and digital resources*" [36] whose objective was to present a methodology for the implementation of the Physics course in the distance modality through the use of information and communication technologies (ICT) and digital educational resources for industrial engineering careers within the Technological Institute of San Luis Potosi, reaching an important finding, which was the confirmation of the effectiveness in the practice of teaching physics in higher education through correctly applied digital mechanisms thus generating significant knowledge.

Connectivity for kinematics compression

The information collected in the logbook and the results of the analysis of the students' answers, recorded in the learning analytics, show that the process of the students in their learning of kinematics concepts produced on the movements, evidenced an adaptation to the new context, interaction and value by the cognitive presence of the materials encountered. Hence, a self-directed learning process was established in network (learn-to-learn) by the students, which achieved several interpretations on

kinematics in their conceptual understanding that were used in the laboratory experimentations, namely:

Student 9: The speed of the ball increases in the first part, remains constant in the middle part and then slows down thereafter.

Student 12: The speed of the ball gradually decreases until it stops.

Student: 6: The speed of the ball remains constant for most of the trip and only decreases at the end of the trip.

Student 7: The velocity of the ball remains constant until the end, with no appreciable deceleration.

The aforementioned allows inferring that the user under a connectivist approach feeds and updates knowledge according to the members participating in multiple connection nodes over time, in which the teaching presence is fundamental since the same one could mediate, guide and feedback in the presented appreciations, and one of the given conceptualizations proves the friction as the cause of the deceleration (student 12). Moreover, as well as it increases at the beginning (student 9), it decreases at the end (student 6), therefore, the ball slows down evidently at the end of the trip. Then, it follows that under a connectivist approach should be supported from a community of inquiry [16], since apart that self-directed learning is promoted through connectivity, there is also: (a) adaptation, where the student makes an assimilation/accommodation to the elements that seem relevant to his context of information exchange; (b) interaction, in the multiple social interactions that require the connected student to react to the diversity of opinions and ideas in which there is an apprehension, modification or criticism to the knowledge, resources or activities that they perform as part of their development at the individual level [27]; and, c) value to cognitive presence, where the connected learner is faced with the need to choose items based on their value, needs and experiences with other individuals [26].

7. Conclusions

In light of the results shown, it could be thought that the presence of the teacher presents little interaction, since students control their own learning. In fact, the connective teaching strategy of kinematics showed that the teacher, far from controlling, should go beyond guiding and mediating the teaching-learning process through ICTs, but should ensure that students create their own network of connectivity for lifelong learning. In this sense, the connective teaching strategy orients openness and autonomy towards the diversity of knowledge and relationships to communicate and share information, since collective knowledge is within reach.

Therefore, the category diversity, allowed to demonstrate that in teaching and learning under a connective vision is essential to consider the category connectivity and access to collective intelligence in both human and non-human elements through ICT and learning networks, which was fundamental for the category understanding of kinematics, in the study of rectilinear motion at constant speed. Although some students provided an intuitive notion of speed, these reasonings characterize the common sense to be able to understand the physical phenomena that surround us without having to go through a mathematization when the object in question slows down, decreases or increases.

To conclude, the presented approach stimulates self-learning in a network and opens a range for the construction of new knowledge by using, reorganizing and transforming knowledge artifacts in different formats (text, sound, video) as well as animations, simulations, etc. The student could have an understanding of kinematics with which he/she moves from a mathematical representation in the form of position-time and velocity-time graphs to a common-sense representation of physical phenomena by studying the properties of rectilinear motion at constant velocity.

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