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To cite this article: C A Pabón-Galán *et al* 2021 *J. Phys.: Conf. Ser.* **2102** 012006

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# Physics learning based on the use of concept maps

C A Pabón-Galán<sup>1</sup>, C A Hernández-Suarez<sup>1</sup>, and L S Paz-Montes<sup>2</sup>

<sup>1</sup> Facultad de Educación, Artes y Humanidades, Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

<sup>2</sup> Facultad de Ciencias Empresariales, Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: cesaraugusto@ufps.edu.co

**Abstract.** Concept maps are graphic learning tools that allow teachers and students to organize, represent knowledge, and visualize the relationships between concepts to promote understanding of physics. This study describes an innovative experience based on the development of concept maps with the aim of analyzing the perception of students in a teacher training program in natural sciences and environmental education at a public university in Colombia. The research subjects were 24 students studying basic physics who used concept maps for learning, and the data were analyzed quantitatively using a non-experimental design. The results show that the trainee teachers learned to elaborate concept maps, valuing very positively their educational applications to improve learning. It is concluded that concept mapping can be used to increase students' understanding and motivation which should help to improve their academic performance.

## 1. Introduction

Concept maps [1-4] are heuristic tools that, through a diagram, help to visualize the relationships and associations between ideas and concepts [5,6] to generate meaningful learning [7]. In general, it uses the problem-solving method that is based on the understanding of ideas [8,9], which generally begins as an answer to a question [10], which are represented in hierarchically structured nodes in the form of a tree with superior and subordinate parts and are connected with linking words on the lines to explain the relationships [11]. Concept maps as a graphic way of representing concepts and their relationships provide teachers and students with a useful resource to organize, synthesize and communicate what they know about a given topic. Therefore, they can be used as didactic resources by the teacher when showing synthetic and structured information about something, or they can be used as learning strategies that students develop when they approach the study of a topic [12].

This study is interested in highlighting the fact that concept maps, used as classroom activities, force those who make them to reflect on their own knowledge, help to visualize the deficiencies of the learning process and allow to represent the evolution in the construction of a person's knowledge or the influence of collaborative learning [13]. The educational use of concept maps is initially grounded in the theory of meaningful learning [14] because they are useful for visual and semantic coding of concepts, propositions, and explanations; it contextualizes the relationships between concepts and propositions [15], thus integrating into the constructivist approach to teaching and learning processes [16], where students' prior knowledge can be interpreted in terms of cognitive schemas, propositions, or concepts [1,17,18]. To promote students' understanding in a constructivist way, one can use concept maps, in which distinguished associations between ideas and concepts are linked through networks and schemes [17,19,20] and, as a result, they understand better [21].



On the other hand, the acquisition and understanding of knowledge is also achieved through social interaction [22], through collaborative student learning [23]. The teaching of physics in teacher training programs in natural sciences plays an important role in the development of the thinking of future teachers, however, the assimilation of this discipline is complicated for most of the students, which is why they do not have the necessary motivation to meet the learning objectives required in their respective academic programs. These difficulties have a negative impact on the development of the training process of these students, which shows the need to look for didactic-methodological innovations that allow them to appropriate the knowledge of physics to achieve the appropriate cognitive level [24].

Finally, there is evidence of positive results on the use of concept maps to improve academic performance [25-27] and enhance student learning. However, despite its use at different educational levels, including higher education, it is still not used correctly. Therefore, the objective of the study is to analyze the perception of teachers in training of a natural sciences program, on the use of concept maps as a tool for learning basic physics.

## 2. Method

A quantitative study model was adopted, and its design corresponds to the non-experimental one using the questionnaire as the data collection tool. Descriptive analysis was chosen as the main statistical analysis method, using SPSS software for the analysis. We worked with only one group due to the availability of the study.

### 2.1. Subjects of the study

The study sample corresponds to students (teachers in training of a natural sciences program at the Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia) who used concept maps to learn physics. The course consisted of 27 students to whom a questionnaire was distributed, but only 24 who were fully completed were considered. Regarding gender, 14 (58.3%) of the students are men and 10 (41.6%) are women. Regarding age, 13 (54.1%) students were between 18 and 21 years old, 7 (29.1%) were between 22 and 25 years old, two (8.3%) were between 26 and 29 years old, and one (4.2%) was more than 30 years.

### 2.2. Procedure

The experience has been carried out in a basic physics course; the contents of the subject are developed in 2 hours of classroom work and 2 hours of independent work, in which the students develop the different contents through activities. The didactic intervention supported by concept maps for learning Physics seeks to improve the training process and at the same time to develop the ability to reflect on one's own knowledge, as well as the use of knowledge representation techniques, among others. For this reason, the intervention has been devoted to explaining the elaboration of concept maps, so that they first develop individually a practical example of a map and then they must make a collaborative map in groups of 2 or 3 students on the subject under study, which must be handed in to the teacher for assessment. Finally, in the hours of independent work, students produce individually or in groups a concept map on the topic of study. At the end of the course, students answered a Likert scale to collect their perception on the use of concept maps.

### 2.3. Data collection technique

The questionnaire used in this research was adopted from previous research on concept mapping [28]; the questionnaire included as a first part the socio-academic characteristics of the students. The second part corresponds to the dimensions on the elaboration (10 items) and educational functions (8 items) of concept maps. The 18 items are closed propositions about which the student must rate his or her degree of agreement on a five-level Likert scale (1 = strongly disagree to 4 = strongly agree); the questionnaire had a content validation based on expert review and a validation for each item in a pilot test on a group of students (n=5). The questionnaire has a moderately high reliability coefficient, obtained by Cronbach's alpha test of 0.83.

### 2.4. Data analysis

For the questionnaire, responses to each question per domain were expressed according to the score given by the Likert scale. The responses were imported into the SPSS software package for analysis. For the interpretation of the Likert scale, it follows the methodological guidelines of Hernández and collaborators [29], which means that in this study scores lower than 2.0 indicate a negative opinion and, for higher than 2.0 is a positive opinion of the students on the use of concept maps for learning natural sciences.

## 3. Results and discussions

Next, the statistics of the dimensions of the Likert scale are shown to assess the degree of acceptance of the students about the use of concept maps for the learning and representation of physical concepts. In addition, the students' perceptions are presented and analyzed for each of the dimensions of the scale; according to Table 1, the mean obtained is 3.0 on a scale of 1 to 4, indicating that students mostly accept the use of concept maps as an educational tool for learning physics.

**Table 1.** Statistics of the Likert scale dimensions.

Dimension	Mean	Standard deviation
Concept mapping	2.6	0.9
Educational functions of concept maps for learning physics	3.3	0.8
Average	3.0	0.9

### 3.1. Concept mapping

In the first part of the questionnaire, 10 items were used to find out the students' opinions on the process of concept mapping; Table 2 shows the wording of these items and the results corresponding to the average of the different categories of the scale (between 1 and 4). The analysis of the results in Table 2 shows that most of the students have found it easy to learn how to make concept maps, but that it takes time to make them properly; among the difficulties that students express when elaborating a concept map are finding the linking words between concepts, followed by the selection of the main ideas, as well as the organization of the spatial distribution of the concepts and finally that it is not easy to structure the knowledge to be represented in the concept map.

Other opinions that stand out are that most of the students feel motivated to learn and design concept maps; they also consider that reflection when making a map is important to represent knowledge well. Finally, students think that concept mapping improves the educational process and favors didactic innovation. In summary, the opinions expressed by the students indicate that there are some difficulties in the learning and elaboration of concept maps, but in general there is a satisfactory evaluation of this process, where the motivating and innovative nature of this type of activity in initial teacher training for the learning of a subject such as physics is highlighted.

**Table 2.** Average of the items of the concept mapping dimension.

Items	Mean
Time is needed to properly develop a map	1.81
It is not easy to structure knowledge to represent it	2.67
I find it difficult to select the main ideas	1.86
It is difficult to organize the spatial distribution of concepts	2.17
I have difficulty finding the words for the links between concepts	1.90
Concept mapping is easy to achieve	3.38
I am motivated by learning and designing a concept map	3.43
Reflection in mapping is important to represent knowledge well	3.17
The concept map is a didactic innovation with respect to traditional teaching	3.30

### 3.2. Educational functions of concept maps for learning physics

In the second part of the questionnaire, 8 items have been used to find out the students' opinions about the educational function of the concept map; Table 3 shows the wording of these items and the results corresponding to the analysis of the relative frequencies of the different categories of the rating scale. The analysis of the data presented in Table 3 shows that students value positively the main educational functions of concept maps for learning physics; most students consider that concept maps favor the organization of ideas in learning and the synthesis of information and organization of physics topics.

In addition, concept mapping forces students to reflect on physics topics to relate preconceptions and construct concepts, which contributes to improving the understanding of concepts and the effectiveness of physics learning; other educational functions are student-centered; most students believe that mapping is a technique for the study of physics that promotes critical thinking and problem-solving skills. They also believe that concept mapping is a resource to improve the explanation of physics concepts and develops the ability to evaluate sources and points of view to select the best option to solve a physics problem.

The use of concept maps has a positive valuation that is reflected in better motivation and in turn probably in the performance of students as stated by [27], a variable that should be investigated as well as collaborative learning [30] and the use of information communication technology (ICT) tools [31]. Therefore, the use of concept maps for learning affects students' learning [32], especially in physics [7,28,33]. As a result, the findings of this study could be used to illustrate the use of concept maps to assess student learning and in turn help in the transformation of educational processes.

**Table 3.** Average of the items of the educational functions dimension of concept maps for learning physics.

Items	Mean
Promotes the organization of ideas in the learning of physics	3.45
Improves understanding of concepts and effectiveness of physics learning	3.23
It allows me to reflect on physics topics, to be able to relate preconceptions and to construct physical concepts	3.25
It favors the synthesis of information and the organization of physics topics	3.47
It is a good technique for the study of physics	2.96
It is a useful resource to improve the explanation of the physical concepts that allow me to solve a problem.	3.19
It promotes my critical thinking skills to solve a physics problem	3.20
Develops my ability to evaluate sources and points of view to select the best option to solve a physics problem	3.46

Finally, the use of concept maps in the teaching-learning process of physics allows classifying and categorizing information; assimilating information, ideas, and concepts; finding connections between various concepts; supporting creative thinking; using graphic and schematic relationships effectively instead of using written or verbal descriptions; creating relationships between already known concepts; helping in problem solving among others [34]. Although this study is background research, it has some limitations for the generalizability of the results. The participating students belong to only one academic program; therefore, for future studies it is necessary to include more respondents from different academic programs. Another limitation is that only quantitative information is analyzed, so it should be complemented in the future with a qualitative study.

## 4. Conclusions

In this study, the opinions of the students who take the subject of basic physics of a teacher training program in natural sciences are exposed, about their experience in a didactic intervention that uses concept maps for the learning and representation of physical concepts; at a general level, it can be stated that students learned to develop concept maps, positively evaluating their educational use to improve their learning. However, it is reflected that the number of participants is not large enough and that they

also belong to a single university academic program, to consider that such results are generalizable; for future research, it is recommended to expand the number of students and academic programs, as well as to carry out a qualitative study to complement the quantitative results. Research should also be done to analyze the opinions of students and teachers about collaborative learning and the use of information communication technology tools to develop concept maps.

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