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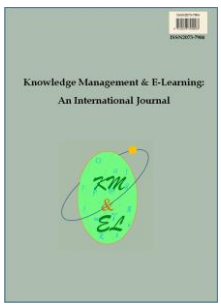
Cristina Valls-Bautista
University Rovira i Virgili, Tarragona, Spain
Juan-Francisco Álvarez-Herrero
University of Alicante, Spain



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Using concept maps to improve pre-service teachers' learning of scientific concepts

Cristina Valls-Bautista*

Faculty of Educational Sciences and Psychology
University Rovira i Virgili, Tarragona, Spain
E-mail: cristina.valls@urv.cat

Juan-Francisco Álvarez-Herrero

Faculty of Education
University of Alicante, Spain
E-mail: juanfran.alvarez@ua.es

*Corresponding author

Abstract: Concept maps can enhance meaningful learning at any level of education. The objective of this study is to investigate the role of creating concept maps in improving pre-service teachers' learning of scientific concepts. The study was carried out with 38 pre-service primary school teachers. After a session introducing concept maps, each participant created an initial concept map based on a given list of concepts. In subsequent sessions, participants further developed the concepts. At the end, each participant created a new concept map using the same list of concepts. Results show that the initial maps were simpler, with limited hierarchical levels, fewer connectors, and a relatively small number of concepts. The final maps demonstrated clear progress in both map structure and content, displaying a greater number of concepts, more hierarchical levels, and the use of more connectors. The final maps also reflected a deeper understanding and more coherent organization of the content. The questionnaire data revealed that the participants viewed concept maps as a valuable tool for their future classroom practices.

Keywords: Concept maps; Pre-service teachers; Science education

Biographical notes: Cristina Valls Bautista has a PhD in Biology and is a professor of didactics of experimental sciences in the Department of Biochemistry and Biotechnology of the Faculty of Educational Sciences and Psychology of the Rovira i Virgili University of Tarragona, Spain. Her main lines of research are: Inquiry-based Learning, Scientific Literacy, and Improving the quality of education through the use of ICT.

Juan-Francisco Álvarez-Herrero is a doctor in Educational Technology, professor of didactics of experimental sciences in the Department of General Didactics and Specific Didactics of the Faculty of Education of the University of Alicante, Spain. His main lines of research are: Inquiry-based Learning, Scientific Literacy, Digital Teaching Competence, and Improving the quality of education through the use of ICT.

1. Introduction

Concept maps have a long history in teaching different subjects and their use extends to all educational levels (Cañas et al., 2015; Kinchin, 2015; Pontes Pedrajas et al., 2015). Maps have been described as heuristic elements that facilitate learning, as elements for reflection (meta-knowledge) and as elements that allow meaningful learning to be evaluated (González Yoval et al., 2004).

The use of concept maps is based on a constructivist view of learning, as well as in the theory of meaningful learning (Ausubel, 1968; Novak & Cañas, 2005). So that students can anchor new knowledge in their previous knowledge. In this way, concept maps give meaning to new learning and it endures over time (i.e., meaningful learning), as the knowledge can later be retrieved and applied in new contexts. The process of meaningful learning and the construction of knowledge is very similar to creating a concept map (Pontes Pedrajas et al., 2015). That is, when students develop a concept map, it provides insight into how a particular topic is organized within their cognitive structure. Concept maps, like our knowledge, are in continuous evolution. They can be expanded with new learning, and sometimes it is necessary to restructure previous knowledge in order to integrate new concepts. In this way, both concept maps and knowledge change throughout the learning process. Along these lines, Novak (1998) defined concept maps as pedagogical tools that allow knowledge to be represented. Nevertheless, Novak and his collaborators later assert that it is essential to implement concept maps within learning environments that actively promote meaningful learning and minimize rote memorization. Simply using concept maps in the classroom does not, in itself, guarantee that students will learn meaningfully (Cañas et al., 2023). Moreover, they emphasize that concept maps should focus on two fundamental elements: content and structure (Cañas et al., 2015).

Pontes Pedrajas (2014) highlights that using maps as a classroom activity enables students to reflect on their learning and identify areas for improvement. In this sense, students can learn to self-evaluate and self-regulate in the learning process. The concept map becomes a tool that can help students to identify what they still need to learn (if they cannot include it in the map, it means they do not understand it), thus realizing a metacognitive process and a higher-order thinking skill (Cañas et al., 2017).

Concept maps are visual representations of the hierarchy and relationships between concepts within a topic or teaching unit (González García & Novak, 2008). Likewise, for anyone to be able to correctly read the concept map, it must contain three elements: concepts, connecting lines (or connections) and connectors (or linking words) (González García & Novak, 2008).

In the teaching and learning process, concept maps can be used for different purposes, such as evaluating the learning process (continuous evaluation), solving problems, understanding how students construct new knowledge, with instructional use, and to enhancing meaningful learning, etc. (Aziz et al., 2017).

Its use in the education transcends all subjects and educational levels. For example, it has been shown to improve learning with very satisfactory results in achieving meaningful learning in a variety of areas and stages such as medicine (Tapia et al., 2018), engineering (Rafael & Justino, 2022), accounting (Sadeghi Dehcheshmeh & Banitalebi Dehkordi, 2021), primary school students in science subjects (Dragoescu Urlica et al., 2019), secondary education students (Calheiro et al., 2020), and higher education students (Chambi Mescco, 2020), etc. Much research and investigation has been conducted into the

improvements in learning obtained by users of concept maps, particularly among future teachers in training (Almulla & Alamri, 2021; Cebrián et al., 2019; Şen & Yilmaz, 2018). All these studies conclude that using concept maps provides improvements in understanding, analysis, and structuring of the concepts worked on, resulting in significant learning.

Novak wondered how a concept map could be assessed and how it could be determined whether a map was good or not. To this end, he developed a list of criteria with which to evaluate the quality of a concept map. However, he emphasizes that maps must be analysed from both a structural and content-based perspectives (Cañas, et al., 2015). Novak highlights that a well-constructed concept map should effectively address the focus question. Moreover, what sets an excellent map apart is its ability to not only provide an answer but also convey it in a clear and well-structured way (Cañas, et al., 2015).

However, there are practically no studies that compare the results before and after receiving training in the basic concepts of how to use concept maps, nor any that examine students' perceptions and feelings about using them. The objective of this research is to investigate the role of creating concept maps in improving pre-service primary school teachers' learning of scientific concepts.

2. Method

2.1. Participants

The experience was carried out with 38 pre-service primary school teachers who were in their second year at Rovira i Virgili University, Tarragona, Spain. Of these, a majority 81.6% (31) were women, and the remaining 18.4% (7) were men, something common in education degrees. The ages were between 18 and 50 years, with the average being 20.82 years. At the beginning of the "*People and Health*" module, students create a concept map using a list of 39 provided concepts. Over the following four weeks, the module focuses on content related to food and nutrition. During this period, students also received training on how to construct concept map. At the end of the module, they were asked to make the concept map again in order to assess the level of achievement.

2.2. Procedure

The steps that have been followed to develop this research are detailed below: The training proposal began with an introductory session explaining what concept maps are, how they are created, and their potential and didactic uses. After this, students were given a list of 39 concepts related to food and nutrition and were asked to create an initial concept map. Several subsequent sessions were dedicated to presenting and exploring the content on food and nutrition in greater depth. Based on this learning, students constructed a final concept map using the same list of 39 concepts. Finally, they completed questionnaires designed to capture their perceptions of concept maps as well as the emotions and feelings they experienced throughout the process.

2.3. Instruments

To analyse the improvement in the development of concept maps, an evaluation was carried out using both quantitative and qualitative criteria. Table 1 shows the quantitative criteria analysed. This quantitative evaluation is based on an adaptation of the work of Galván-Pérez and Gutiérrez-Pérez (2018) in which the original criteria have been maintained, but the ranges in each of the levels have been adapted so that each level contains a third of the total values. To analyse the improvement of concept maps at a qualitative level, 3 criteria proposed by Galván-Pérez and Gutiérrez-Pérez (2018) were analysed, adapting the criteria related to the content of classroom work.

Table 1
Criteria and levels for the quantitative evaluation of concept maps

Criteria	Low level	Medium level	High level
Number of concepts	1-12	13-26	27-39
Number of hierarchy levels	1-2	3-4	5-6
Number of connections	1-10	11-20	21-30
Number of connectors	1-5	6-12	12-17

In this way, as shown in Table 2, the evaluation focused on several qualitative aspects. First, it was assessed whether the relationship between nutrients appeared in the concept map (classified as yes/no). Additionally, the analysis examined whether the students identified the nutritional content of foods (i.e., whether they contain carbohydrates, lipids, proteins, vitamins and minerals). It was also evaluated whether the function of these nutrients was described, and whether the nutrients were classified according to their function in the body (energetic, plastic or regulatory). Furthermore, in this section, it was also analysed whether students were able to provide examples of foods rich in each type of nutrient. To analyse the qualitative improvement of the maps, visual impact was also assessed, using three-point scales: poor visual (the map's organization is unclear and difficult to read quickly), quite visual (the organization is fairly clear and can be read quite easily and quickly), very visual (the organization is very clear enabling and quick reading). An additional item evaluated was the level of connector selection. This was assessed, using a four-point scales: no connectors, low selection level (the selected connectors do not support reading comprehension), medium selection level (the selected connectors slightly support reading comprehension), high selection level (the selected connectors clearly facilitate reading comprehension).

Table 2
Criteria for the qualitative analysis of the evolution of concept maps

Map content analysis (Yes/No)	Visual impact	Connector selection
What does food contain	Poor visual	Connectors do not appear
Function of nutrients	Quite visual	Low selection level
Classification of nutrients	Very visual	Medium selection level
Examples of foods rich in each nutrient		High selection level

In addition, it was assessed how the students had experienced of creating the concept maps and the perceived level of difficulty associated with this task. For this, the questionnaire published by Pontes Pedrajas et al. (2015) was used which consists of 12 closed-ended items to which students responded using a Likert scale (1: not at all agree, 2:

slightly agree; 3: quite agree; 4: strongly agree). The questionnaire is composed by 12 propositions (see Appendix I). Likewise, students also responded to eight statements (using the same Likert scale) about the pedagogical usefulness that they believe concept maps have (Pontes Pedrajas et al., 2015). The questionnaire includes eight questions (see Appendix II). Finally, they answered six open questions to assess and express their feelings throughout the experience in using the concept maps.

2.4. Statistics

For the statistical analysis of the quantitative data, the statistical program IBM SPSS Statistics 25 was used. The qualitative data were analysed with a Microsoft Excel sheet.

3. Results

3.1. Quantitative analysis of map quality

The quantitative analysis of map evolution, the number of concepts that the students were able to use in the concept map was determined. The total number of concepts was 39; these were distributed equally into three levels (low, medium, and high). As can be seen in Table 3, in the initial map, 58% of the students were able to use between 27 and 39 concepts (high level) in the construction of the initial map, while in the final map, the high level represents 95% of the students. The hierarchy analysis indicates the number of levels of hierarchy the concept maps present, with a maximum of six levels. In the initial map, half of the students were able to create maps with a medium hierarchy level of between three and four levels. In the final map, however, the high hierarchy level represented 92% of the students. A similar evolution is seen in the number of connections: in the initial map, half of the group could make a medium level of connections, whereas in the final map, almost 87% of the students were at a high level of connections. Logically, there is a direct relationship between the number of concepts used in the map and the number of connections. The number of connectors is the aspect in which they have improved the least since initially only 23% could use a high level of connectors between 12 and 17, and in the end, this percentage rises to 39%.

To analyse the evolution of the concept maps at a qualitative level, it was examined whether the students were able to capture the following ideas on the map: i) what nutrients foods contain (proteins, carbohydrates, lipids, mineral salts and vitamins) ii) what function each nutrient performs (energetics: lipids and carbohydrates; plastics: proteins; and regulators: vitamins and mineral salts) iii) select examples of foods that are rich in each type of nutrient, iv) analyse the visual impact (visually the map is easy to understand), v) analyse the type of connectors selected (connectors are the key element of a map and whether or not they make it easier to read).

When analysing the foods included in the students' maps, it is observed that a high percentage initially include this idea, reaching almost 95% in the final map (see Table 4). In relation to whether the students capture the function of nutrients, a marked evolution is observed, initially being only 34% and exceeding 84% in the final map. The results relating to the classification of nutrients are very similar initially; less than 50% of the students include it on their map, whereas in the final map, almost 87% place it on their map. Conversely, a high percentage of the students reflected in the initial map examples already

reflected foods that contain each type of nutrient in high proportions. On the other hand, the visual impact of the maps has improved between the initial and final versions; that is, in the final map, the percentage of "*very visual*" maps has increased, and that of "*not very visual*" maps has decreased. The final indicator analysed is the selection of connectors, which has shown the least improvement. As can be seen, a certain percentage of students do not use connectors in either the initial map final map. Even so, the percentage of students who do not use connectors or who use low-level connectors has decreased while the percentages of medium- and high-level connectors has increased very slightly between the initial and final map.

Table 3
Comparison of quantitative analysis between the initial and final maps

	Initial map	Final map
Nº of concepts		
Low level (1-12)	0.00%	0.00%
Medium level (13-26)	42.00%	5.00%
High level (27-39)	58.00%	95.00%
Nº of hierarchy		
Low level (1-2)	2.60%	0.00%
Medium level (3-4)	55.30%	7.90%
High level (5-6)	42.10%	92.10%
Nº of connections		
Low level (1-10)	7.90%	0.00%
Medium level (11-20)	52.60%	13.10%
High level (21-30)	39.50%	86.90%
Nº of connectors		
Low level (1-5)	36.80%	36.80%
Medium level (6-11)	36.80%	23.70%
High level (12-17)	26.30%	39.50%

Table 4
Comparison of qualitative analysis between the initial and final maps

	Initial map	Final map
What does food contain		
No	15.80%	5.30%
Yes	84.20%	94.70%
Function of nutrients		
No	65.80%	15.80%
Yes	34.20%	84.20%
Classification of nutrients		
No	52.60%	13.20%
Yes	47.40%	86.80%
Examples		
No	15.80%	10.50%
Yes	84.20%	89.50%
Visual impact		
Poor visual	47.40%	36.80%
Quite visual	44.70%	47.40%
Very visual	7.90%	15.80%
Connector selection		
There are no connectors	15.80%	13.10%
Low selection level	50.00%	39.50%
Medium selection level	31.60%	39.50%
High selection level	2.60%	7.90%

3.2. Self-perception analysis

Of the 38 students who participated in the research, only five students (13.2%) recognized that this was their first experience of using concept maps. To evaluate self-perception of using the maps, the students responded to the following 12 propositions with a Likert-type response indicating their degree of agreement (from 1: do not agree at all to 4: strongly agree), which has been described in the methodology section.

The results of the evaluations are shown in Table 5. Only 4 of the 12 aspects present a rating above "*quite agree*" (3), and these are: (A) the need for time and effort; (B) lots of practice and patience; and (K) importance of the work of reflection and recognition that this is a methodological change with respect to traditional teaching. Propositions H, I, and J present averages below 3; these assessments are poorly accepted. The remaining five propositions were formulated negatively (C, D, E, F, and G), and all of them had averages below three. The fact that it was difficult to find the connections between the concepts (G) was the proposition with the lowest ratio (2.16). This means that this task was not too difficult for the students, since it was formulated negatively. It is also interesting to note that aspect (I) "*I have felt motivated and happy when learning to create concept maps*"; It is the one with the least dispersion of responses (standard deviation of 0.948 and variance of 0.899), and therefore a greater consensus in the students' responses.

Table 5
Perceived experience of creating concept maps

	A	B	C*	D*	E*	F*	G*	H	I	J	K	L
Mean	3.39	3.55	2.74	2.89	2.68	2.89	2.16	2.89	2.58	2.89	3.37	3.11
Typical deviation	0.595	0.602	0.724	0.798	0.662	0.798	0.855	0.764	0.948	0.863	0.675	0.689
Variance	0.353	0.362	0.523	0.637	0.438	0.637	0.731	0.583	0.899	0.745	0.455	0.475

Note. * Propositions were formulated negatively

To find out what future teachers think about the educational functions of concept maps, they responded to eight closed questions using a Likert scale (from 1: do not agree at all, to 4: strongly agree), which has been described in the methodology section. The results obtained are presented in Table 6.

Table 6
Comparison of qualitative analysis between the initial and final maps

	A	B	C	D	E	F	G	H
Mean	3.5	3.45	3.34	3.61	3.5	3.45	3.08	3.34
Typical deviation	0.558	0.602	0.669	0.547	0.558	0.645	0.587	0.669
Variance	0.311	0.362	0.447	0.299	0.311	0.416	0.345	0.447

In this case, all of the propositions are formulated positively, hence all of them obtain ratings higher than three (fairly agree). Being the proposition (D): "*Concept maps favour the synthesis of information and the organization of contents*", the one that obtains a higher rating, while aspect (G): "*Concept maps constitute an activity that develops the creativity of the author of the concept map*", which obtains a lower degree of agreement.

18.4% of the students (7) recognized that they already knew what was explained in class about concept maps, 71.1% (26) recognized that some of the content was familiar, others did not, and only 10.5% (5) said not know in advance what was explained in class

about concept maps. Among the justifications given in this question, 11 responses stand out that agreed in stating that in the training received, they had learned more about how to structure and use connectors in concept maps. Furthermore, five students stated that the training had allowed them to delve deeper into the technique of creating concept maps, while four said that it allowed them to know how to differentiate concept maps from mental maps.

86.8% of students (33) believe that concept maps have helped them to learn significantly, while the other five students do not believe this. Among the reasons that were most repeated in the justification of these answers are: it facilitates understanding (14), it allows synthesis (10) and organization of the contents (10), they are easy to handle and understand (6), they allow concepts to be related (6) and it is a very visual tool (6) that allows obtaining a global vision (6) of a set of contents.

All students (100%) see concept maps as a useful tool in the teaching-learning processes, these being the most notable reasons: it allows the synthesis of content (12), the possibility of working on it before and after seeing the contents (12), serves to organize the concepts (8), as well as to have an easy understanding (7) and a global vision of a topic (6).

At the beginning of the experience, 9 students admitted that they had already used concept maps as a study tool before. To these are added another 20 who, as a result of this experience, make a total of 76.3% of the students admit that they will use the concept maps in the future. While the remaining nine students (23.7%) say they will not use them. Among the reasons given by the first are: they are useful (10), they help to summarize (6), they are easy to study (5) and they allow knowledge to be structured. On the other hand, those who will not use them argue that they prefer other tools (7), or that using concept maps requires a lot of time (2).

3.3. Perceptions of concept mapping experience

On the other hand, the students' feelings were collected revealing notable differences in how they felt when creating the initial and final concept map. These are shown in Table 7, with their frequencies in parentheses.

Table 7
Perceived feelings during the completion of the initial and final concept map

Initial feelings	Final feelings
Lost (12)	Insurance (29)
With difficulties (10)	Confident (6)
Good (4)	Very good (5)
Confusing (4)	Good (4)
Insecure (3)	Free (2)

The students (9) who say that they will not use concept maps as a study tool recognize that they do not know if they will use them with their future students when they become teachers. While the other 29 (76.3%) affirm that they will use concept maps when they become teachers. The former argues that there are more effective tools available and that depending on the student body, concept maps could be effective or not. The latter group insists that concept maps are effective, useful tools, since they allow a global vision and organize the content being studied.

Regarding the final open question of the questionnaire, which asked students to comment on what they consider to be the most relevant aspects of their experience of using concept maps, there are a wide of variety of answers. However, four topics that are mentioned frequently also stand out. Two of these topics are negative: namely that is a very subjective tool that it requires a lot of time, while the other two positives: namely that is a very visual tool and that it allows you to organize and structure content easily. Below are four examples of responses given by the students, one referring to each argument.

> *"I think it is a very subjective concept, depending on the student it will go well or badly, therefore, we cannot force them to do it, but we can teach them" [ALU_03]*
>
> *"To make a map, you have to have a lot of free time, be focused and know how to identify the key concepts" [ALU_05]*
>
> *"It is useful to visually present the syllabus and helps improve the organization of the syllabus" [ALU_18]*
>
> *"It is a useful tool to structure ideas and have a global knowledge of the entire syllabus" [ALU_24]*

Although the proportion of male students (18.4%) is not representative compared to that of female students (81.6%), quite interesting differences are observed in the following two items. First, regarding "*It is difficult to organize the spatial distribution of the concepts on the map*", it is much more difficult for men (0.66 points more) to spatially distribute the concepts on the map than for women. Second, regarding "*It is easy to become familiar with the technique of creating concept maps*", it is much easier for women to become familiar with the technique (0.57 points more) than for men. No notable differences are seen in the rest of the items.

Three of the five students who were using concept maps for the first time, considered that they had helped them learn significantly. And of those who had previously used three students consider that they had not helped them learn. Something similar happens when we consider their future use as a study tool. Three of those who have used them for the first time, who will use them again, while seven of those who have already used them, who will not use them as a study tool. The same pattern emerges when they are asked if they will use them with their students in the future A total of nine students say they do not know if they will use them (two of those who have discovered them through this activity and seven of those who are already knew them).

Among the 33 students who believe that concept maps have helped them learn significantly, 28 will use them with their future students, while five do not know if they will. Practically the same pattern emerges when they are asked if they will use concept maps as a study tool, and that is that although 33 recognize that they help them learn significantly, four of them will not use them. These are the same 33 students who consider concept maps to be useful tools that have helped them learn significantly, and useful tools in the teaching-learning processes, which greater validity to the results presented here.

4. Discussions

The quantitative analysis of the evolution of concept maps present improvement in three of the four analysed aspects. Almost all of the students have obtained a high level in the number of concepts used (i.e., implies having used more than two thirds of the listed

concepts). The second aspect that has improved substantially has been the level of hierarchy of the maps since in the final maps with a very high percentage of the students' presented maps, with a high level of hierarchy (between five and six levels). The number of connections that students are able to create has also reflected a significant improvement, with a higher percentage reaching high levels. These results are consistent with those of Galván-Pérez and Gutiérrez-Pérez (2018) who analyse concept maps before and after a didactic intervention in the third year of Compulsory Secondary Education (ESO). Using the same criteria as in the present study and they observe that while the initial maps are at low to medium levels for all the items analysed, the final maps are at medium to high levels.

The last aspect analysed the quantitative analysis was the ability to place connectors to each connection line to provide meaning and promote an accurate reading of the concept map and this aspect improved the least. This result is not surprising since, according to Cañas et al. (2017), the construction of propositions and more specifically, selecting linking phrases between concepts is a task that requires the use of higher-order skills. Precisely, this characteristic of concept maps is what, according to Ballester Vallori (2007), makes them one of the most appropriate instruments to promote significant learning, since student must connect the presented concepts coherently and use the appropriate prepositions.

In relation to the qualitative analysis of the evolution of the concept maps of the six aspects analysed, the students have shown notable improvement in two of them, reflecting the function of nutrients classifying each type of nutrient. Some aspects showed no improvement since the initial results were good, such as in explaining what the nutrients contain or in exemplifying foods rich in each nutrient. Conversely, the aspect that shown the least improvement, was the selection of connectors or propositions that facilitate fluid reading of the concept map and a clear understanding, coinciding with one of the aspects also analysed in the quantitative part. In this aspect, it should be noted that in many cases the students have used the same connector for different connections, making reading monotonous and repetitive. In some cases, the connectors chosen were not the most appropriate since they did not fit the syntax of the phrase. In this sense Cañas et al. (2017) maintain that in the preparation of concept maps the most important thing is the process of creating them and not the final result since during their preparation, place the concepts in the appropriate part of the map and above all select the linking phrases or connectors. These aspects require higher-order skills. So, if we provide students with a list of concepts and even in the first few times they are provided with a scaffold or skeleton of the concept map, these higher- order skills are not affected. Furthermore, concept maps also serve as a valuable tool for identifying concepts that students have not yet fully grasped or have misunderstood. As Cañas et al. (2015) point out, they can help reveal misconceptions that may otherwise go unnoticed. In the present study, the use of concept maps has been integrated into a broader instructional strategy aimed at fostering meaningful learning and moving away from purely rote memorization. This approach aligns with the perspective of Cañas et al. (2023), who emphasize that for concept maps to truly enhance meaningful learning, they must be embedded within teaching practices that support this type of learning. If concept maps are introduced in contexts dominated by rote learning, students may still produce the maps, but meaningful learning is unlikely to occur. Therefore, it is essential to ensure that the use of concept maps is consistent with pedagogical approaches that promote deep understanding.

On the other hand, in the analysis of the students' self-perception of using of concept maps based on a questionnaire by Pontes Pedrajas et al. (2015), it has been possible to verify how pre-service primary teachers learn quickly, motivated and easily to develop

concept maps, giving great importance to the reflection work that this entails, as well as recognizing that it is a methodological change regarding traditional teaching, which is very necessary (Buehl & Fives, 2011; González García et al., 2010; Gutiérrez Esteban et al., 2011; Pontes Pedrajas et al., 2015). Among the qualities that they recognize in concept maps, what stands out is that they are seen as resources that favour the synthesis of information and the organization of content, allowing reflection, better understanding and a spatial and overall vision of the content worked on (Chambi Mescco, 2020; Coma-Roselló et al., 2018; García-Franco et al., 2020).

Regarding the student initial feelings, they expressed confusion, insecurity, and sense of being lost. However, after the training and in the completion of the final concept map, they expressed feelings of security, confidence, or even feeling free. In this sense, it is worth noting that concept maps also allow us to improve the feelings and anxiety caused by the studies to be carried out to pass an exam (Payant et al., 2019), or are even used for beneficial therapeutic purposes (Hughes & Baylin, 2020).

Although some students consider this concept mapping tool to be very subjective or personal, as well as requiring a lot of time to master and use it, a large majority of them will use it for their own learning and with their future students (Marín, 2021), to improve visualization, organization and structure of the contents to be worked on.

This study has some limitations. Firstly, the sample size was small, it was only possible to collect data from 38 pre-service primary school teachers. Secondly, it would also be interesting to compare the evolution of learning between a control group and an experimental group.

5. Conclusion

This study reveals that pre-service primary school teacher perceived significant improvements in their learning of scientific concepts after using concept maps. They recognized concept maps as powerful tools for organizing, visualizing, reflecting on, and understanding the content they engage with. Notably, this study also highlights an important shift in students' perceptions: although many initially feel disoriented, lost, or confused when first introduced to concept maps, after receiving targeted training, they begin to demonstrate increased confidence, security, and even a sense of autonomy in their use. A significant majority of the participants expressed their intention to incorporate concept maps into their future teaching practice in primary education. However, a small number remained hesitant, arguing that concept maps may not be equally beneficial for all learners and may require considerable time and skill for effective implementation.

Author Statement

The authors declare that there is no conflict of interest.

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ORCID

Cristina Valls-Bautista https://orcid.org/0000-0001-5583-5695

Juan-Francisco Álvarez-Herrero https://orcid.org/0000-0002-9988-8286

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Appendix I

Questionnaire on experience of creating concept maps

- It takes a lot of time and effort to build good concept maps.
- Repeated practice and patience are important.
- I have experienced doubts or confusion while learning how to use concept maps.
- It is not easy to structure the knowledge that you want to represent on a topic.
- It takes a lot of work to select the key concepts of the topic.
- It is difficult to organize the spatial distribution of the concepts on the map.
- I have had difficulty finding the words for the links (connectors) between concepts.
- It is easy to become familiar with the technique of creating concept maps.
- I have felt motivated and happy when learning to create concept maps.
- I find it an interesting or fun teaching activity.
- The reflection work carried out when developing a concept map is important to represent knowledge well.
- This type of activities (use of concept map) represents a methodological change with respect to traditional teaching.

Appendix II

Questionnaire on the pedagogical use of concept maps

- Concept maps favor the organization of memory and the retrieval of information.
- Concept maps improve understanding of content and the effectiveness of learning.
- Concept maps force you to reflect on a topic, to be able to relate previous concepts and build new ideas.
- Concept maps favor the synthesis of information and the organization of content.
- Concept maps can be a good study technique.
- Concept maps can become a useful teaching resource to improve the explanation of a topic.
- Concept maps constitute an activity that develops the creativity of the author of the concept map.
- Concept maps can be useful for making presentations and promoting communication in the classroom.