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Development of Metacognitive Skills Based on a B-learning Environment in a Didactics of Topology Course

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A R T I C L E I N F O

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A B S T R A C T

This research presents the results of the implementation of a B-learning environment for a Didactics of Topology course, built with the objective of developing metacognitive skills in a group of preservice mathematics teachers. A verbal protocol analysis is conducted of some exercises proposed in the classroom using the software for qualitative analysis of data ATLAS.ti. In addition, these results are compared to students' perceptions of their metacognitive skills, which were identified through the validated Spanish version of the metacognitive awareness inventory (MAI). Findings show the efficacy of the learning environment in developing habits related to metacognition. We also achieved identifying inaccurate perceptions of the students regarding their cognitive regulation processes.

1.Introduction

In different fields of knowledge, several authors have been engaged in the study of the mind (Kiefer and Trumpp, 2012; Gerbier and Toppino, 2015), which has allowed establishing that the set of mental and dynamic skills related to information processing refers to cognition (Miller and Wallis, 2009). Some examples of cognitive processes are attention, memory, reasoning, problem solving, among others. Based on the foregoing, metacognition arises, defined as the knowledge that subjects have about their own cognitive processes and the control they have on them (Flavell, 1979).

Some studies have concluded that students exhibiting high metacognitive skills focus their attention on the information they need to learn, they plan learning episodes, choose strategies, evaluate their lessons, and constantly monitor the aforementioned processes, which leads to improving learning achievement. Therefore, they exhibit a better academic performance compared to students exhibiting low metacognitive skills (Rickey and Stacy, 2000; Tobias and Everson, 2009; Young and Fry, 2008). Furthermore, some studies related to mathematics, life sciences, and language learning have evidenced that it is possible to develop this type of skills in students with different levels of education (Coutinho, 2007; Huertas and López, 2017; Zohar and Barzilai, 2013).

Similarly, it has been concluded that Web-based learning environments stimulate the development of metacognitive skills in students with different levels of education (Ke, 2008; Kwon, Hong, and Laffey, 2013; Zimmerman and Tsikalas, 2010) since they allow students to: 1. analyze learning tasks and design a strategic plan to solve them, 2. apply strategies to answer the tasks and conduct constant monitoring and control with the purpose of improving the quality of the lessons, 3. establish judgements on their performance, which leads them to self-evaluate their efforts and set new goals according to the results, as well as debug or change the implemented strategies (Narciss, Proske, and Koerndle, 2007).

Considering the foregoing, this research presents the results of applying a proposal of Web-based learning environment, which consisted of a Didactics of Topology course that sought to develop metacognitive skills in students through the use of a learning environment in modality B-learning (Khan, 2005; Osguthorpe and Graham, 2003; Singh, 2003). The course included face-to-face activities and others available in the Moodle platform, characterized by implementing metacognitive activators in each one of the developed units. This article presents the findings of the research conducted with the objective of establishing the impact that a B-learning modality course has on the development of metacognitive skills.

2.Cognition Components

According to Schraw and Dennison (1994), these components can be subdivided in several categories. The first component,

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knowledge of cognition, refers to the skills of the subject to self-evaluate their strategies to develop a certain task. It is comprised of three categories, with which this skill is more specifically identified, which are declarative knowledge, procedural knowledge, and conditional knowledge. The second component, regulation of cognition, is defined as the skills of the subject to apply their knowledge about cognition in the development of a proposed task. It is comprised of five categories, which are planning, organization, monitoring, control, and evaluation.

With the purpose of identifying this type of skills, it is possible to find in the literature different strategies. For example, building of questionnaires that establish questions related to the aforementioned categories (Schraw and Dennison, 1994; Mokhtari and Reichard, 2002); some studies that use more sophisticated tools, such as the use of software for qualitative analysis of data taken from systematic observations (Larkin, 2009); as well as the use of different analysis protocols which seek to identify the use of these skills to develop exercises in specific areas (Artzt and Armour, 1992).

However, it is important to clarify that it is not the only valid approach that can be taken of this conception. For example, in Hacker, Dunlosky, and Graesser (1998), there is another type of subdivision of metacognition into two metacognitive components denominated metacognitive knowledge and metacognitive monitoring, which are pretty similar to the categories proposed by Flavell (1979), Jacobs and Paris(1987), and Schraw and Dennison (1994).

3.Blended Learning

Blended learning, or B-learning, is a method of teaching-learning that arises with the objective of satisfying current society's learning needs, by creating strategies for the student to approach the content of a certain course in a flexible way, through the development of face-to-face and virtual activities in which they can interact with other course students and teachers. The adequate use of this method represents certain advantages for students, such as pedagogic wealth, simplifying access to knowledge, interacting with colleagues, teacher feedback, reduced costs, among others (Osguthorpe and Graham, 2003).

Singh (2003) proposes five dimensions comprising the B-learning modality, which consider resources, strategies, and reliability. The first one classifies this modality in online learning and offline learning depending on how the student accesses the materials, resources, and instruction throughout the course. The second one classifies the work strategies that the student can use to grasp the course content into individual and collaborative. The third one separates blended learning into structured and non-structured depending on the formality of the resources used for its development. The fourth one refers to the way how the student can acquire the knowledge, which in this case is classified aware acquisition and unaware acquisition. Lastly, the fifth one identifies the physical resources that must support this model of learning are identified.

4.Verbal Protocols

The interest in knowing thought processes of the subjects has increased since the middle of the last century, initially in the area of psychology and subsequently in other areas, such as education and anthropology. Thought processes, according to the approach proposed by Newell and Simon (1972), consist of a sequence of mental steps or events implemented during the development of a task, which is why those parties interested in this type of research have always tried to improve the methods that allow identifying this type of processes.

Ericsson and Simon (1980) developed an information processing technique to establish reliable reports of the completed interventions, which is based on identifying subjects' ideas while completing the exercise of thinking aloud when developing a cognitive process. This method is important because it is an effective way of ascertaining the evolution of learning processes in students. Verbal protocol analyses identify the subject's forms of processing and actions observed through the oral answer to an instruction, test, or task. This type of technique for qualitative data gathering has advantages because of its flexibility since subjects, initially, have no restrictions when answering the proposed tasks.

Verbalization processes can be classified in two ways. Concurrent verbalizations, which capture information as the subject develops the task, and retrospective verbalizations, where the subject resorts to long-term memory to establish strategies based on previous conceptions (Ericsson and Simon, 1993).

5.Methodology

This research conducted a case study in a group of preservice mathematics teachers in a private university in the city of Bogotá, Colombia, with the purpose of evaluating the development of metacognitive skills, based on a sequence of proposed exercises and tasks during the development of the course Didactics of Topology, which was offered in the B-learning modality with the aid of the Moodle platform of the university where the intervention was conducted. The research was developed in three stages: diagnostic assessment, training, and final assessment.

Participants had completed more than 50% of the program, therefore, during the intervention, it was assumed that they had the basic tools to approach the disciplinary concepts of the course. For the purposes of maintaining subjects' privacy, they are identified in this research with the letters D, L, and M.

Sixteen face-to-face sessions were conducted for four months, during which the course's disciplinary contents were approached, in addition to proposing tasks to be developed in the classroom and platform, which involved the course's mathematics conceptions, and were aimed at students developing planning, organization, monitoring, control, and evaluation habits. At the same time, four exercises were completed. The first one was a diagnostic assessment, the following two were training, and the last one a final assessment, which were recorded on video, in which students were asked to think aloud to identify the procedures used when solving the task.

Finally, a diagnostic was conducted, which sought to identify the perception students had on the use of metacognitive skills in their learning through the Spanish version of the MAI instrument, "Inventario de Habilidades Metacognitivas", which appears validated in Huertas, Vesga, and Galindo (2014). This results were compared to the data obtained in the verbal protocols, which were interpreted with the aid of the ATLAS.ti qualitative data analysis software.

6.Data Collection

Data collection included the verbal protocols, written records of the solutions of proposed tasks in the classroom, records of the suggested exercises on the virtual platform, and lastly, record of the answers obtained from applying the "Inventario de Habilidades Metacognitivas" questionnaire.

Students were previously trained in the verbalization of their ideas during the development of a learning task, so that they would apply the technique when interacting with the environment and developing the proposed exercises. To analyze the data obtained from the verbal protocols, the following subcategories were proposed, takid by Jacobs and Paris (1987) and Schraw anng as basis the components and categories defined Dennison (1994):

Each one of these categories has the objective of identifying the processes that involve cognition knowledge and regulation that are manifested by the student when performing a task, which in this case are problem solving and readings related to the area of Topology and Didactics.

7.Web-based Learning Environment

For this research, a Web-based Learning Environment was designed and implemented in the Moodle platform to develop a Didactics of Topology course. The environment contained five units, one introductory and four theoretical, and was characterized by presenting metacognitive activators according to the components proposed by Schraw and Dennison (1994). The lesson units are described below:

The objective of the introductory unit was to present students with the content of the course and some conceptual referents about metacognition, and didactics of topology through videos related to the subject matter (See Figure 1).

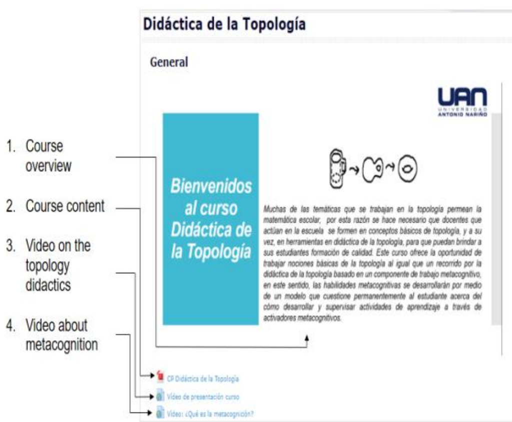

Figure 1. Introductory Unit Description

Unit 1 presented the epistemological development of Topology, the most relevant problems that motivated its origin, the process that led to its development based on Geometry, how some of the branches of study that currently exist in this area emerged, its main differences, and finally, some applications of Topology in other fields of study were discussed.

The resources of the unit include a learning guide, a video, an article, and three metacognitive activators: 1. Planning my learning, 2. Monitoring and controlling my learning, and 3. Reflecting on my learning. In the first one, the student had to estimate the times to develop the learning tasks, establish goals, and identify strategies to develop the proposed activities (López et al., 2012; Zhang and Quintana, 2012). In the second one, the novice was questioned about the results of the planning, they were suggested changes according to goal compliance, and were asked about concept comprehension (Flavell, 1979; Moos and Azevedo, 2008; Schraw and Denninson, 1994). Finally, in the third one, the student had to establish value judgements about the scope of the goals, learning task compliance, and the effectiveness of the implemented strategies (Hannafin, Hannafin, and Gabbitas, 2009; Lin, 2001).

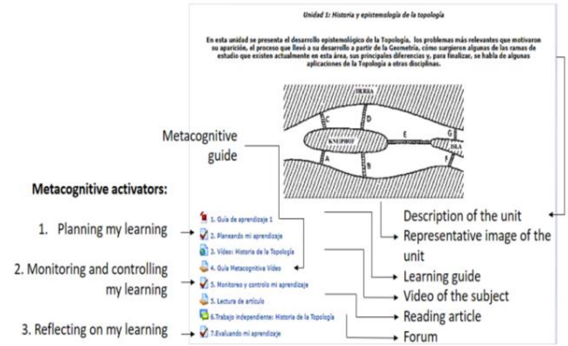

Figure 2. Unit 1 Description

Unit 2 addressed theories of didactics of mathematics applied to Topology, some basic concepts from this branch of mathematics determined by space, forms, and distance were introduced with the purpose of showing that the intuitive notions of Geometry are not directly related to the theory proposed by Euclid, but rather that the intuitive notions of Geometry are related to basic concepts of Topology. Based on the foregoing, it is shown why it makes sense to extend Van Hiele's spatial reasoning model and Piaget's spatial representation theory (George, W, 2017) to the learning of Topology.

This unit presented metacognitive activators in all of its exercises, similar to those described in unit 1. A workshop on Piaget and Van Hiele was developed, which presented conceptual aspects on teaching of topology and different cognitive activities that should allow the student to reflect on their lessons. To complement, constructivism theory in teaching of mathematics was addressed.

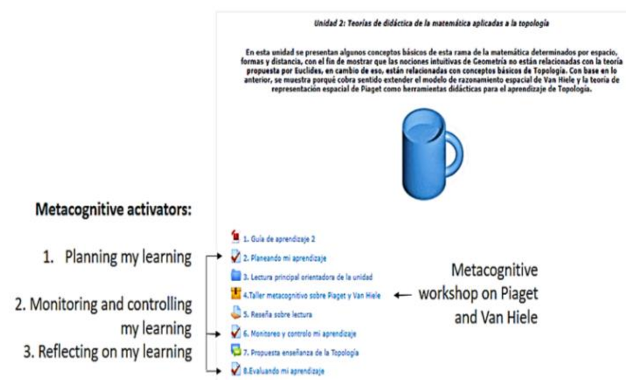

Figure 3. Unit 2 Description

Unit 3 presented the basic notions of General Topology, among them the definition of topologies, topological space and open set. Additionally, was shown how these definitions are the only tools needed to approach more general topological concepts such as continuity, connected space, and compact space. This unit presented activators and two metacognitive virtual objects emphasizing the use of metacognitive strategies in the analysis of a video in three moments.

The first moment asked the student about actions that should be completed before beginning a learning episode through questions such as: Do you ask yourself questions about the subject matter before watching an educational video? Which strategies do you implement when analyzing educational videos? Do you set learning goals when watching an educational video? Among others. The second moment asked the novice about the level of comprehension of the video's topics and the effectiveness of the implemented strategies. Lastly, the third moment, led the student to ask themselves about the comprehension of the video's contents through questions such as: Was the strategy implemented in the analysis of the video's contents the most effective? Did you attain with the proposed learning goals? Among others.

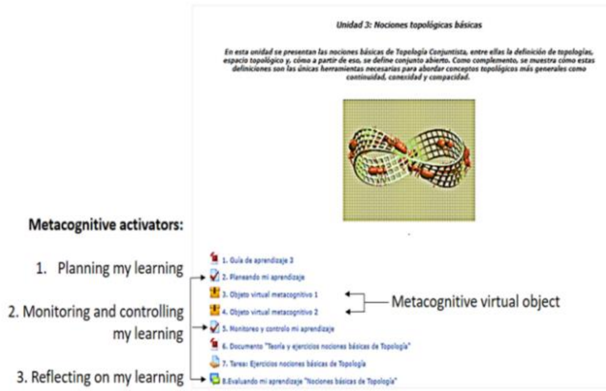

Figure 4. Unit 3 Description

Unit 4 developed the basic concepts of graph theory, together with some of its applications in different fields of study. In addition, using mathematical games, the definitions of Eulerian path and Hamiltonian path were presented, showing strategies to guarantee their existence and algorithms for their construction.

In this final unit, the student developed a metacognitive virtual object proposed based on graph theory, which followed the same structure of the moments described in the virtual object of unit 3.

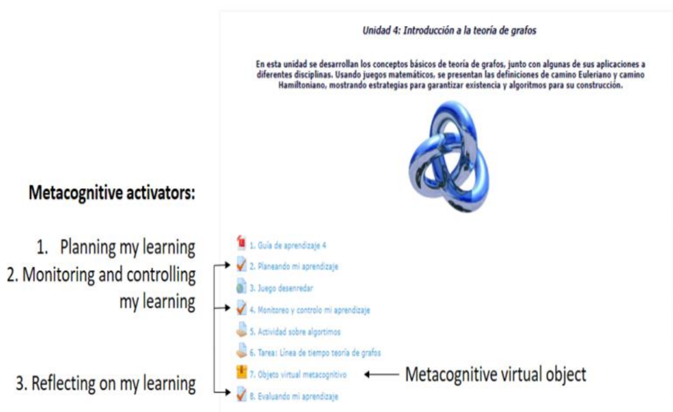

Figure 5. Unit 4 Description

8.Results

This section describes the findings obtained from the implementation of the Web-based Learning Environment, the completion of several training tasks involving metacognitive activators, exercises proposed in the classroom through which to assess the effectiveness of the environment in developing metacognitive skills, and lastly, the application of instruments to identify the perception of the students on their skills about knowledge and regulation of cognition.

The exercises, from which the data appearing in table 2 were collected, were applied in different stages of the course. The main objective of these exercises was to identify students' evolution as the course progressed. Before interacting with the environment designed for the course, a diagnostic assessment, E1, was conducted, in which each one of the skills of the students about cognition and regulation of cognition were assessed. Subsequently, during the course's development, two training exercises, E2 and E3, were conducted, where the use of metacognitive activators was stimulated through specific instructions that the student had to follow to complete the task. Lastly, a final exercise, E4, was conducted, in which students had to complete a task where they could autonomously put into practice the skills developed in the course.

The four sessions were recorded on video and based on the analysis of each verbal protocol, the data appearing in table 2 were obtained, which shows the frequency with which each student participating in the research made use of the skills related to their cognition knowledge and regulation, according to the categories and subcategories proposed in table 1.

E1 was built with the idea of identifying previous knowledge of the students on the course's contents. In addition, we wanted to identify their level of awareness in using their cognitive skills and if there was any type of regulation of their cognitive processes when completing tasks.

In this exercise, students exhibited a low regulation of their cognitive processes and in the episodes where they manifested knowledge of their cognitive skills, they exhibited deficiencies in the disciplinary knowledge needed to solve the task. For example, in the episode shown below, student D manifests knowledge of their cognitive skills in an assertive way ADK, together with an evident lack of conceptual knowledge.

"ADK-D-E1: I am thinking that this is not equal, because, because here in parenthesis it says that everything is to the c power, but this one that is over here is not to the c power, and this one that is over here, this one is equal to this one."

Another case we found in this exercise, different from the behavior observed in student D, is the behavior of student L, who manifested they did not have the cognitive skills to do the task NDK. The following episode shows the verbalization done by the student:

"NDK-L-E1: I read to leave things as they were, but no, I do not remember having seen this U to the m power."

Additionally, the student displayed a lack of intent in solving the proposed task. Instead they manifested that they did not remember having seen those conceptions in any other course of the program. From the foregoing, we can conclude that students did not feel confident in verbalizing the ideas used to solve the task.

Another noteworthy aspect found in this exercise, was that cognitive process regulation performed by students basically focused on identifying if they had achieved a satisfactory result in the proposed task. In other words, students did not identify the exercise as an initial diagnostic assessment of their skills, but rather identified it as a test in which they had to obtain the correct result. The regulation episodes manifested are the following:

"RER-D-E1: It is false because I am going to write there everything that is over here, I am going to put it, all of it is to the c power. Because here it says that, that theorem can be said…hence this one is to the c power."

"RER-M-E1: For me the equation is false, because the third indication says that X does not belong to the union of the equation, then the equation that is represented in the previous equation does not hold."

It is important to highlight that in these two episodes, both students use a similar argument to justify the solution of the proposed task. In this case, saying that the equation appearing in the task was false and consequently, it was not possible to reach a solution using any type of technique related to the disciplinary area of the course.

As previously mentioned, during the course, students developed training exercises containing the following metacognitive activators: 1. Planning my learning, 2. Monitoring and controlling my learning, and 3. Reflecting on my learning. The data presented from this development stage of the course are E2 and E3, since all of the students participated in these exercises and they were developed at strategic implementation times.

E2 consisted in representing through a graph diagram the possible solutions of the Tower of Hanoi game. The episodes presenting greater frequencies in the verbalizations of this exercise correspond to cognition regulation, in the subcategory of instruction monitoring, IMR, because students developed the exercises aided by reflective questions that asked about comprehension and regulation of their cognitive process. For example, in this exercise, student M manifests an instruction monitoring episode IMR, in the following way:

"IMR-M-E2: The Tower of Hanoi disk game. A test of intelligence with the Tower of Hanoi game. The Tower of Hanoi game consists in changing the disks of tower one to tower three, with the condition that you cannot move more than one disk at a time and that I cannot place, and you cannot place a big disk over a small one."

Another subcategory that stands out in regulation cognition is strategy evaluation, SER, since the student was influenced through instructions to reflect on the effectiveness of the strategy implemented during the development of the exercise. The foregoing is evidenced in the following episodes:

"SER-D-E2: No, I do not think so. I do not think so because anyways the strategy is easy. I remember that it was with what it said, with odd numbers I start the tower that I am not going to use, and with even numbers of disks I use the tower I have to get to. That is the only thing I remember about the strategy. And well nothing else, I do not believe there is anything else."

"SER-M-E2: Yes. Well I think that when one already knows, it is easier to draw the graph, since it is my first time it is a little difficult for me, but I already understand it, and now I, I, I can handle it."

The episodes allow observing that students apply strategies that they had already implemented and that they recognized as effective to develop this type of tasks. They also indicate that the first attempt at using the strategy can be complex, but as of the second try the implementation can be simpler.

As it can be observed in the following episodes, the use of activators encouraged students to plan and evaluate the times used to develop the proposed tasks, since when the students were asked if the time management was adequate, the following impressions were obtained from the students:

"TER-D-E2: Yes of course. Oh, although it can be faster, but no, I think so, even though I could do it faster."

"TER-M-E2: It was little, very little, very little time."

The verbalizations allow observing that student D establishes that the times were adequate to answer the learning tasks. On the other way, student M indicates that the planned times were not enough, which evidences opposing perceptions regarding the difficulty of the exercise discussed.

On the other hand, regarding cognition knowledge, the proposed activators allow reflecting on the implemented strategies during the development of the exercise, like in the example below:

"APK-D-E2: The only thing I remember about this game is that when it was an odd number, I began with the tower that I wanted to leave it at, in this case let us say here. When it was an even number, then it was with the opposite tower, now I remember how it goes teach. Well, there we are moving this here, ready here, this here. Ok, I am restarting the game. We are going to move this here…"

Similarly, E3 consisted in reading about the relevance of Leonhard Euler's contributions to mathematical literature, in which was included some metacognitive activators. Once again, the episodes allow establishing that these activators influence the appearance of a greater frequency of statements related to regulation of cognition, for example:

In time planning, where student L asserts: "TPR-L-E3: I plan to spend 10 minutes because I am going to read it three times to properly understand the reading."

In setting learning goals, subject D verbalizes: "GPR-D-E3: the learning goal set for the following activity is the events that influenced the mathematical discoveries made by Euler."

In strategy evaluation, the novice D indicates: "SER-D-E3: In my case, I think so, but I know let us say that there are better Reading strategies, in my case, I say so."

Regarding cognition knowledge, some examples of verbalization in this direction are presented:

In assertive declarative knowledge, student L manifests understanding the contents appearing in the reading: "ADK-L-E3: Yes, this one is interesting, it is cool. Yes, yes I understand it because I do, yes I understand it because it mostly explains Euler's journey since he was a boy, since he had a prodigious mind, that he published the proof of the formula for simply connected polyhedrons, afterwards he invented, besides the disciplines he had already invented, other disciplines, the theory of infinite series, superior algebra, calculus of variations. He also ended up researching the harmonic series."

In assertive procedural knowledge, student D evidences knowledge of their skills to complete the reading: "APK-D-E3: Yes, I understand it, since by reading it a second time, I mostly read what I underlined, highlighted. I understood what the reading was about."

In conditional knowledge, student M verbalizes that they had difficulties answering one of the reading questions: "NCK-M-E3: I do not remember seeing harmonic series, false. Is writing why, not required?"

In general, it was possible to establish that during the development of E2 and E3 there were a greater number of regulation of cognition episodes compared to knowledge of cognition . The foregoing because the exercises were aided by metacognitive activators.

Exercise E4 was designed so that students would autonomously solve the proposed task and thus determine the frequency of use of metacognitive skills. In this case, the task consisted of applying the four-color theorem to a proposed map and at the same time, build a graph that represented it. In the training exercises, E2 and E3, students were indicated in which phases they should manifest and regulate their cognitive skills, while in E4, no type of indication was made in this sense, waiting to observe the student's spontaneous behavior when solving the task.

When analyzing the verbalizations, we found that the frequencies in E4 were inferior to those identified in the training exercises, E2 and E3; nevertheless, these frequencies were higher regarding to the initial exercise, E1.

We also identified that students verbalize more about their solution strategies, APK and NPK compared to the episodes of knowledge of their cognitive skills, ADK and NDK. Furthermore, in this exercise, the assertive procedural knowledge, APK, frequencies are higher than in all the other cognition knowledge subcategories.

When comparing to exercise E1, it is evidenced that assertive procedural knowledge, APK, is greater in exercise E4. Below, is presented an example in which the student manifests having a solution strategy:

"APK-L-E4: We are going to begin this activity, first of all, the strategy I am going to use is that I am going to, going to read the exercise."

In E4, cognition regulation appeared more frequently than the others, since in this case the TPR, GPR, FCOR, FVLOR, and FHLOR subcategories displayed a significant increase compared to the results of the frequencies in the initial and training exercise, where these subcategories were absent. To that regard, it is possible to observe the following statements:

"FVLOR-L-E4: "and the strategy that I am going to use is, first, I am going to make a graph on top of the map and afterwards I will do it on the side, which is what we are being asked to do, ready start."

"FVLOR-M-E4: "Now I am coloring each vertex in with a different color so that I do not … that no adjacent vertex has the same color."

In both statements, it is possible to see that students use visual aids. In the first case, a map and in the second one, a graph to solve the proposed task.

9.Temporal Analysis

With this research, we achieved in identifying a satisfactory progress in the development of students' metacognitive skills. The foregoing, probably as a consequence of the students' training through the use of metacognitive activators proposed in the course's tasks and in the Web-based Learning Environment.

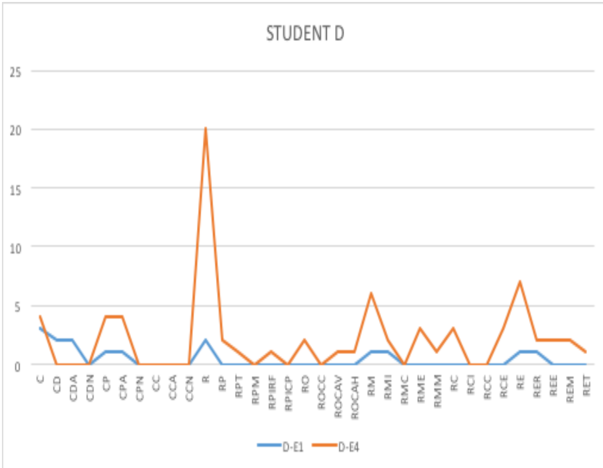

Figure 6. Frequencies of Student D

In this case, it is suitable to only analyze E1 and E4, given that both exercises sought to identify the metacognitive habits autonomously manifested by students, with the difference that in E1, the subjects had not received any type of training, while in E4, they had already interacted with the learning environment.

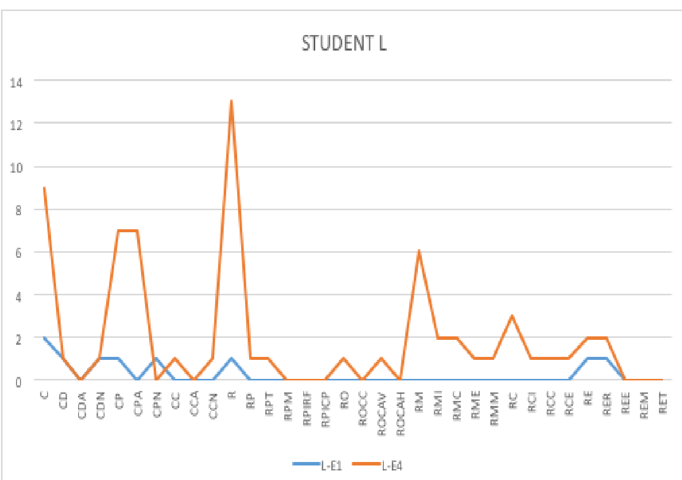

Figure 7. Frequencies of Student L

In E4, it is possible to identify an increase in the confidence when verbalizing knowledge about concepts related to the proposed task and, in addition, are evidence strategies and confidence in the use thereof.

However, the most notable progress appear in the category of regulation of cognition, since, while in the first case of knowledge of cognition, the frequencies of the episodes went from 3 to 4 in student D (See Figure 6), from 2 to 9 in student L (See Figure 7), and from 2 to 11 in student M (See Figure 8). In the case of regulation episodes, more significant progress was found. As it can be observed in Figure 6, where student D went from 2 episodes in the first exercise, related only to instruction monitoring and results evaluation, to 20 episodes in the fourth exercise that included more sophisticated metacognitive habits, such as organization focused on heuristic learning and identification of physical resources.

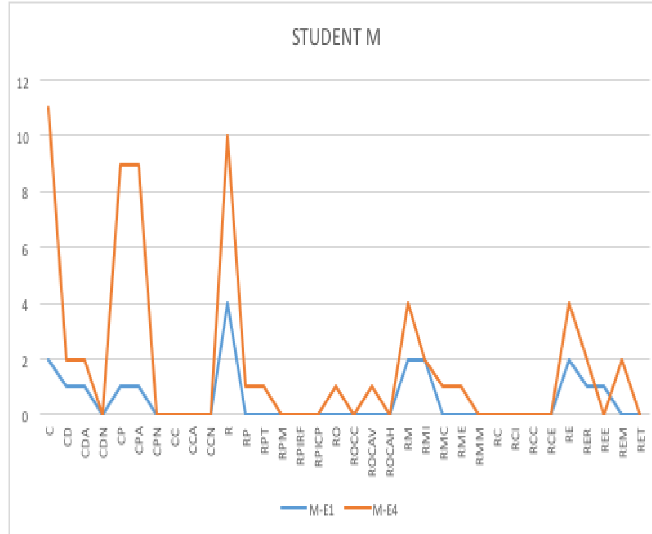

Figure 8. Frequencies of Student M

In student L, a similar behavior is identified (See Figure 7), going from 1 cognitive regulation episode in E1 to 13 episodes in E4. Lastly, student M shows less significant progress (See Figure 8), going from 4 cognition regulation episodes in E1 to 10 episodes in E4. The foregoing shows the effectiveness of the learning environment in the development of metacognitive habits of regulation.

10.Perception Analysis

An interesting exercise in any knowledge area is identifying the coherence between what one subject perceives about their skills and what can be identified by observing their performance. In this research, we wanted to compare the frequencies obtained from the verbal protocol analysis obtained from exercise E4, where students spontaneously completed the proposed tasks and had interacted with the learning environment, to the perception the novices had regarding their metacognitive skills at the end of the course, which was identified through the implementation of the "Inventario de Habilidades Metacognitivas" (Huertas, Vesga, and Galindo, 2014).

The instrument manages a Likert scale between 1 and 5, where 1 represents that the subject completely disagrees with the question, which is interpreted as a perception of low use of metacognitive skills, and 5 represents that the subject completely agrees with the question, in other words, the subject perceives that they frequently manifest the use of metacognitive skills. Table 3 shows the means, rounded to the nearest integer, of the data obtained from applying the "Inventario de Habilidades Metacognitivas" instrument to the students of the group where the research was conducted.

We can observe in table 3, that student D perceives that they frequently use metacognitive-type skills when solving a task, having a mean of 4 in the main categories, in other words, in "Knowledge of Cognition -K and in "Regulation of cognition-R", but when compared to the frequencies obtained from the verbal protocols, it is verified that that student exhibits fewer episodes of "Knowledge of cognition -C", with a frequency less than half than that exhibited by students L and M (See table 2). However, in the case of episodes of regulation of cognition, completely different results are found, since the episodes of regulation of the student D nearly doubled the episodes of students L and M.

On the other hand, student L perceives that they do not frequently use regulation skills when completing a task, having a mean of 3 in regulation of cognition, the lowest in the group of participants; however, when compared to the regulation episodes collected from the verbal protocol analysis, a frequency greater than that of student M is evidenced, who displayed a higher perception in the means of the questionnaire.

In addition, we can observe in table 3 that the subcategory where the highest perception means are located is control. However, when we look at table 2, we find completely different results, as this same subcategory has one of the lowest frequencies in the category of regulation, way below the subcategories monitoring and evaluation which have lower means in table 3. This shows that even though students exhibit an evident improvement in regulating their cognitive processes, they still have an inaccurate perception of the way how they perform that regulation.

11.Conclusions

The findings allow identifying that the learning environment proposed in the course in which the research was conducted, stimulates the development of metacognitive skills, mainly in the category of regulation of cognition, which concurs with some studies conducted in this area (Valencia et all, 2019; Castiblanco, 2018; Ke, 2008; Kwon, Hong, and Laffey, 2013; Zimmerman and Tsikalas, 2010). The foregoing is probably due to the metacognitive activators implemented in the Moodle platform and incorporated in the training exercises.

Additionally, it can be verified that the metacognitive activators set in the virtual platform and in each one of the exercises proposed in the course, allowed planning times, setting goals, applying strategies, performing monitoring and control actions, and evaluating the results obtained at the end of a learning episode. Regarding the B-learning modality in which the course was implemented, there is a positive response from students since, in addition to the development of metacognitive skills, the exercises allowed providing assistance in theoretical concepts worked in the course (Araque et al. 2018).

Based on the analysis conducted on the students' verbalizations in the proposed exercises with the aid of the ATLAS.ti software, we conclude that it is possible to foster the use of their metacognitive skills through virtual learning environments. The verbalization exercises require the student to verify what they think in the middle of a cognitive process and require them to organize their ideas to be expressed. In this case, the training was within the framework of a Didactics of Topology course in a preservice mathematics teachers program, but the model learning environment proposed can be implemented in other types of courses. In this sense, the research contributes a proposal for the evaluation of metacognitive skills for qualitative studies based on the Works of Jacobs and Paris (1987) and Schraw and Dennison (1994).

It is also possible to observe that students perceive they use metacognitive-type skills on a daily basis. This perception, although it does not necessarily concur with the results of the test applied at the end of the study, allows asserting that by having more clarity about their metacognitive skills and how to use them, students set, as a desirable goal, to be good at managing them, fact that is achieved when a conscious comprehension of the possibilities of their use in academic improvement is reached.

Considering the results obtained in the cognition knowledge component, it is necessary for future research to think in activators focused on the categories of this components. In the case of declarative knowledge, it is convenient to implement activators that facilitate identifying the knowledge a subject has about their learning, their skills, and the use of their cognitive abilities. Regarding procedural knowledge, the activators must question the subject on employing their learning strategies. Finally, in conditional knowledge, the activators should question the knowledge a subject has about when and why to use learning strategies.

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Table 1. Cognition components.

Component	Category	Description	Subcategory	Description
Knowledge of cognition - K	**Declarative Knowledge - DK**	Knowledge a subject has of their learning, their skills, and use of their cognitive abilities.	**1. Assertive Declarative Knowledge - ADK** **2. Negative Declarative Knowledge - NDK**	1. Subject manifests knowledge of their cognitive skills to solve a proposed exercise. 2. Subject manifests they have no knowledge of their cognitive skills to solve the exercise.
	Procedural Knowledge - PK	Knowledge a subject has on employing their learning strategies.	**1. Assertive Procedural Knowledge - APK** **2. Negative Procedural Knowledge - NPK**	1. Subject evidences strategies that can be used to solve the exercise. 2. Subject evidences they do not know any strategies that can be used to solve the exercise.
	Conditional Knowledge - CK	Knowledge a subject has about when and why to use learning strategies.	**1. Assertive Conditional Knowledge - ACK** **2. Negative Conditional Knowledge - NCK**	1. Subject is confident in the strategy used to solve the exercise. 2. Subject is not confident in the strategy used to solve the exercise.
Regulation of cognition - R	**Planning - PR**	Statement in which subject defines study times, sets learning goals, and chooses resources.	**1. Time Planning - TPR** **2. Goal Planning - GPR** **3. Identifying Physical Resources - IPRPR** **4. Identifying Previous Knowledge - IPKPR**	1. Subject defines times to solve the exercise. 2. Subject defines learning goals in solving the exercise. 3. Subject establishes the available physical resources to develop the exercise. 4. Subject establishes the available concepts and strategies to solve the exercise.
	Organization - OR	Statement where the subject organizes the activities chosen in planning.	**1. Organization Focused on Concepts - FCOR** **2. Organization Focused on Visual Learning - FVLOR** **3. Organization Focused on Heuristic Learning - FHLOR**	1. Subject focuses their attention on relevant concepts in learning episodes. 2. Subject makes diagrams that help them understand the information analyzed. 3. Subject establishes schemes to search for solutions to the proposed exercises.

Monitoring - MR	Description of the possible problems in solving the task.	**1. Instruction Monitoring - IMR** **2. Concept Monitoring-CMR** **3. Strategy Monitoring - SMR** **4. Goal Monitoring - GMR**	1. Subject reflects on the understanding of the exercise's instructions. 2. Subject reflects on the concepts used to solve the problem. 3. Subject considers the different ways of solving the problem. 4. Subject supervises compliance of established goals.
Control - CR	Sentence where the subject corrects the identified problems and adjusts the strategies to improve their performance in the development of the task.	**1. Instruction Control - ICR** **2. Concept Control - CCR** **3. Strategy Control - SCR**	1. Subject changes their procedures when they verify that they did not understand the instructions correctly. 2. Subject identifies the misused concepts and restates them. 3. Subject changes the strategies as they develop the exercise.
Evaluation - ER	Description of the degree of effectiveness identified in the implemented strategies.	**1. Results Evaluation - RER** **2. Strategy Evaluation - SER** **3. Time Evaluation - TER** **4. Goal Evaluation - GER**	1. Subject establishes a value judgement on the task's results. 2. Subject reconsiders the strategies used in the development of the task. 3. Subject evaluates if the times used were aligned to that planned. 4. Subject reflects on the scope of the proposed goals at the end of the learning episode.

Table 2. Verbal Protocol Frequencies

	D-E1	D-E2	D-E3	D-E4	L-E1	L-E2	L-E3	L-E4	M-E1	M-E2	M-E3	M-E4
K	3	16	8	4	2	6	9	9	2	20	8	11
DK	2	3	4	0	1	2	5	1	1	3	3	2
ADK	2	3	4	0	0	2	5	0	1	2	3	2
NDK	0	0	0	0	1	0	0	1	0	1	0	0
PK	1	11	2	4	1	1	1	7	1	12	2	9
APK	1	11	2	4	0	1	1	7	1	12	2	9
NPK	0	0	0	0	1	0	0	0	0	0	0	0
CK	0	2	2	0	0	3	3	1	0	5	3	0
ACK	0	2	0	0	0	1	1	0	0	1	1	0
NCK	0	0	2	0	0	2	2	1	0	4	2	0
R	2	22	19	20	1	20	20	13	4	15	19	10
PR	0	1	2	2	0	4	1	1	0	0	1	1

TPR	0	1	1	1	0	4	1	1	0	0	1	1
GPR	0	0	1	0	0	0	0	0	0	0	0	0
IPRPR	0	0	0	1	0	0	0	0	0	0	0	0
IPKPR	0	0	0	0	0	0	0	0	0	0	0	0
OR	0	0	0	2	0	0	0	1	0	0	0	1
FCOR	0	0	0	0	0	0	0	0	0	0	0	0
FVLOR	0	0	0	1	0	0	0	1	0	0	0	1
FHLOR	0	0	0	1	0	0	0	0	0	0	0	0
MR	1	13	14	6	0	13	15	6	2	10	13	4
IMR	1	12	14	2	0	13	15	2	2	10	13	2
CMR	0	0	0	0	0	0	0	2	0	0	0	1
SMR	0	1	0	3	0	0	0	1	0	0	0	1
GMR	0	0	0	1	0	0	0	1	0	0	0	0
CR	0	2	0	3	0	0	1	3	0	0	1	0
ICR	0	2	0	0	0	0	1	1	0	0	1	0
CCR	0	0	0	0	0	0	0	1	0	0	0	0
SCR	0	0	0	3	0	0	0	1	0	0	0	0
ER	1	6	3	7	1	3	3	2	2	5	4	4
RER	1	2	0	2	1	0	0	2	1	1	0	2
SER	0	3	1	2	0	3	1	0	1	3	2	0
GER	0	0	1	2	0	0	1	0	0	0	1	2
TER	0	1	1	1	0	0	1	0	0	1	1	0

Table 3. Means of the “Metacognitive Awareness Inventory”

Categories	D	L	M
Knowledge of Cognition - K	4	4	4
Declarative Knowledge - DK	4	4	4
Procedural Knowledge - PK	5	4	4
Conditional Knowledge - CK	5	4	4
Regulation of Cognition - R	4	3	4

Planning - PR	5	3	4
Organization - OR	4	3	4
Monitoring - MR	5	3	4
Control - CR	5	4	5
Evaluation - ER	4	3	4