MENDIVE
REVISTA DE EDUCACIÓN
Translated from the original in Spanish

Cognitive independence to design Biology experiments with a frame introduced by opening sequence

Independencia cognoscitiva al diseñar experimentos de Biología con un cuadro introducido por secuencia de apertura

Independência cognitiva ao projetar experimentos de Biologia com um quadro introduzido pela sequência de abertura

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ABSTRACT
The experimental work in students of the Bachelor of Biology Education is carried out following reproductive guidelines, which hinder the fulfillment of the requirements of the professional model. This demands a teacher capable of independently solving problems of school practice, including experimental work. A possible solution may be the application of a didactic resource that facilitates the design of experiments independently. The objective of this work was to evaluate the cognitive independence of students of Bachelor of Biology Education, in the design of experiments using as a didactic resource a chart that is introduced from an opening sequence. The intervention was carried out in a sample of 10 first-year students from the 2016-2017 academic years. A randomized complete block statistical design was used to compare cognitive independence in completing parts of the chart and students against each other. As a result, there was a marked tendency towards execution that gradually decreased, while independence and motivation increased. Significant differences were observed in the achievement of independence in the completion of the parts of the chart and among the students, for whose attenuation a differentiated work was carried out.

Keywords: didactics of experiment, science teaching, teaching resource, experiment, problem solving.

RESUMEN
El trabajo experimental en estudiantes de Licenciatura en Educación Biología se realiza siguiendo guías reproductivas, que obstaculizan el cumplimiento de las exigencias del modelo del profesional. Esto demanda un profesor capaz de resolver, con independencia, problemas de la práctica escolar, incluido el trabajo experimental. Una posible solución puede ser la aplicación de un recurso didáctico que facilite el diseño de

experimentos de forma independiente. El objetivo de este trabajo fue evaluar la independencia cognoscitiva de estudiantes de Licenciatura en Educación Biología, en el diseño de experimentos, usando como recurso didáctico un cuadro que se introduce a partir de una secuencia de apertura. La intervención se realizó en una muestra de 10 estudiantes de primer año del curso 2016-2017. Se empleó un diseño estadístico de bloques completos al azar para comparar la independencia cognoscitiva, al completar las partes del cuadro y a los estudiantes entre sí. Como resultado, se constató una marcada tendencia a la ejecución que disminuyó gradualmente, mientras aumentaba la independencia y motivación. Se observaron diferencias significativas en el logro de la independencia, en el completamiento de las partes del cuadro y entre los estudiantes, para cuya atenuación se realizó un trabajo diferenciado.

Palabras clave: didáctica del experimento; enseñanza de las ciencias; recurso didáctico; experimento; solución de problemas.

RESUMO

O trabalho experimental em alunos do Curso de Licenciatura em Ensino de Biologia é realizado seguindo orientações reprodutivas, que dificultam o cumprimento dos requisitos do modelo profissional. Isso exige um professor capaz de resolver, de forma independente, problemas da prática escolar, inclusive trabalhos experimentais. Uma possível solução pode ser a aplicação de um recurso didático que facilite o desenho de experimentos de forma independente. O objetivo deste trabalho foi avaliar a independência cognitiva de alunos do Bacharelado em Biologia da Educação, na concepção de experimentos, utilizando como recurso didático uma tabela que é introduzida a partir de uma sequência de abertura. A intervenção foi realizada numa amostra de 10 alunos do primeiro ano do ano letivo 2016-2017. Um desenho estatístico de blocos completos randomizados foi usado para comparar a independência cognitiva, completando as partes da tabela e os alunos uns contra os outros. Como resultado, houve uma tendência acentuada para o desempenho que diminuiu gradualmente, enquanto a independência e a motivação aumentaram. Diferenças significativas foram observadas no alcance da independência, no preenchimento das partes da tabela e entre os alunos, para cuja atenuação foi realizado um trabalho diferenciado.

Palavras-chave: experimento didático; ensino de ciencias; recurso didático; experimento; resolução de problemas.

INTRODUCTION

In pedagogical practice of training teachers of Biology, shows those students have gaps in skills development related to the practical and experimental work. One of the shortcomings consists in the manifestation, in them, of the tendency towards execution (García, Leyva & Guerra, 2017).

On the other hand, in the teaching of Biology for the training of teachers, there are many teachers who drag to the disciplines of the university level, methods and style s typical of secondary education, which turns the process of teaching into a repetitive act that, in the best of cases, increases the volume of content to be learned by the student, but does not provide learning strategies that lead to decision-making and cognitive independence (Zilberstein & Olmedo, 2014).

The foregoing is in contradiction with the professional model of the Bachelor of

Education, Biology career, which aims to train a professional with a broad profile, capable of independently solving the dissimilar problems that arise in the base link, the school. This coincides with the need to contribute to training our students to be scientifically competent in the greatest number of situations, which requires redefining some actions that take place in the classroom (Márquez & Sardà, 2009).

According to the literature searches conducted by the authors of this work, and the development of the teaching of the experiment in science classes, it is possible to identify two trends in correspondence with the role of the student: the experimental work as "cooking recipes" and inquiry practices.

The first trend is identified with the traditional paradigm. It is characterized by the abandon of thought, the focus efforts in mechanical learning, the repetition of exposure and practice. The necessary protagonism of the student is obviated and they are increasingly criticized. According to Tenreiro & Márquez (2006, cited by Domènech, 2013), these are " laboratory works , which are often limited to more or less spectacular illustrative demonstrations in which students assume the role of spectators and the uncritical execution of "recipes of kitchen", without getting involved intellectually" (p.250).

It is criticized, above all, his emphasis on making measurements, calculations, the absence of fundamental aspects for the construction of scientific knowledge and discussion of the relevance of the work to be done, clarifying the issue that is inserted, participation of the students in the hypothesis formulation, the design of the experiments and the analysis of the results obtained (Carrascosa et al., 2006).

The second trend focuses on the protagonism of the student and their intellectual involvement. It is framed in conceptions that require the application of the scientific research method such as: inductive discovery learning and research learning.

These examples of focused work from this trend are directed research (Carrascosa et al., 2006), the practice of scientific methodology (Gonzalez, 2005), the transformation of the statement s of the slogans of laboratory work to promote skills intellectual and social skills in students and habits of scientific reasoning (Carp et al., 2012), the problematization of experimental activities (Peres & Marques, 2013), the increase in the degree of openness and participation of students in writing in sequence of practical laboratory work format of inquiry (Domènech, 2013), the open activities of inquiry in the laboratory (Crujeiras & Jimenez, 2015; González & Crujeiras, 2016) and reformulation of scientific competence for the competencies proper to the school science (Via & Izquierdo, 2016) just to name a few.

One of the aspects that characterizes learning through inquiry in the laboratory is the design of experiments (Crujeiras & Jiménez, 2015); Carrascosa et al. (2006) proposed the open nature of the situations presented and proposed "give full importance to the development of design and planning of experimental activity by students" (Carrascosa et al., 2006, p.164). It is or presupposes that the teacher uses the didactic resources and teaching strategies necessary to promote the independent work of the students.

Carp, et al., (2012) propose to modify the traditional statements (indications in the form of a "recipe") of the practical work guides in General Chemistry to stimulate students to propose experimental designs. The new statements are formulated in such a way that students "think about what they have to do" (Carp et al., 2012, p. 169).

González (2005) makes a proposal focused on the use of scientific methodology where they first present the method that allows to carry out the type of experiment to be studied, then they offer a concrete example of the use of the method and, finally, they propose to the students the realization of practices related to this method, but in the form of problem situations that require the design of experiments to reach the solution.

Considering the aspects already analyzed and that in the authors' opinion should contribute to the cognitive independence in the experimental work of the students who are being trained as future Biology teachers, it is proposed, first of all, to present traditional laboratory practices as experimental tasks, since it confronts the student with situations that require, not only to carry out an experiment, but to design it.

Secondly, to solve such tasks a set box design the experiment as a procedure that allows materializing mental actions corresponding to the action called orientation and it has prospective character, it is to say, it can anticipate the actions and necessary operations, which, in the case of Biology, are aimed at observing the biological structure or reproducing the biological phenomenon under study under the conditions of the experiment.

Objective: To evaluate the cognitive independence of Bachelor of Education students Biology, in the design of experiments, using as a didactic resource a table that is introduced from an opening sequence.

MATERIALS AND METHODS

The study was carried out at the Central University "Marta Abreu" of Las Villas, in the 2016-2017 academic year. The population was made up of students from the Bachelor of Education, Biology career. The sample was intentionally selected, made up of the 10 students who took the subject of their own curriculum: Skills to Work with Biological Material in the 2016-2017 academic years. The design table was applied in the solution of experimental tasks of this subject.

To achieve the objective proposed, an inclusive approach, based on dialectical materialism, followed determined methods, techniques and tools that allowed the proposal and analysis of data. In the design followed, three groups of methods are identified: theoretical, empirical and statistical. Then it explains how each one was applied.

Empirical methods:

- Design complete block to the random: to assess cognitive independence in the design of the experiment as one of the procedures of the method of qualitative experimental tasks solution of Biology.
- Observation: for the qualitative assessment of students in the design of experiments.
- Interview: for the diagnosis of the students about their work in the teaching biological laboratory.
- Pedagogical test: (each of the tasks used in the tests) for the evaluation of the cognitive independence of the students in each test.

Statistical methods: For the analysis and interpretation of the data obtained from the practical application. From the Descriptive Statistics: charts and graphs and Statistical Inference: test of the inter subject effects for fixed factors and Duncan test. Then, it deepens in analogy method by considering cornerstone of research. Its use was possible because Physics and Biology are experimental sciences, a feature that is also manifested when they are assumed as subjects. Due to the differences between both sciences and in their teaching, it was not possible to directly transfer the design framework of the experiment proposed by Leyva and Guerra (2012) for Physics, but a new one was proposed for Biology by García, Leyva and Guerra (2017), on the basis of the previous one.

They took into account, in addition, existing methodological guidelines for the teaching of biology as a subject, which contains the methodological design of laboratory practices as part of practical activities. In them, there were considered the level of development achieved by students, so that new demands on the actions and operations allowed a higher level of development in knowledge and skills, but called "recipes" not all of the above is possible.

For this reason, in the training of Biology teachers, it is necessary to prepare them to carry out experimental tasks that require the application of knowledge, greater cognitive independence and the development of logical thinking. In the design table of the experiment to solve experimental tasks in Biology, as a didactic resource, traditional aspects of laboratory practices are maintained as a form of organization of the teaching process, but new concepts are incorporated to avoid the immediate execution of the student in solving this kind of task.

The design box of the experiment corresponds to the function of the action called orientation. Each of the components of said table was conceptualized as follows: experimental system: as the set of natural biological objects, substances and tools necessary to reproduce the phenomenon or prepare the biological structure for study; observation system: such as the set of technical means and the requirements to these and the experimental system, necessary for the observation of the phenomenon or the structure; the operative technique: consisting of the set of operations that are carried out with the experimental system and the observation system to reproduce the phenomenon or prepare the biological structure for its study and carry out the experiment (García, Leyva & Guerra, 2017).

To determine the content of the components of the design table of the experiment, the factors involved in their selection and specification were proposed. These are: structure to be observed (EO) phenomenon to be reproduced (FR), selection and preparation of the biological sample (SPMB), effect or characteristic that reveals the phenomenon or the biological structure (ECRFE) and the form of data processing (FPD) (García, Leyva & Guerra, 2017).

Structure to be observed: the requirement of the experimental task can be directed to the study of a biological structure or a biological phenomenon. In the first case, the structure must be specified and the row corresponding to the factor to be reproduced must be left unfilled. In the second case (this is determined by the previous factor), as the phenomenon is always linked to a certain structure, then this structure will also be determined.

The determination of the structure to be observed gives content to the experimental system because, once declared, its dimensions must be taken into account to choose the instrument and other suitable accessories for its observation. This gives content to the observation system. This factor also gives content to the operative technique, since the corresponding actions regarding the use and operation of the experimental system must be declared to achieve the observation of said structure.

Phenomenon to reproduce: in order to detect the properties of a biological phenomenon in the laboratory, it is necessary to reproduce it experimentally, so that these properties are manifested. In this sense, the equipment of the experimental system must be determined, which ultimately depends on the equipment available in the laboratory and prescribes the minimum essential elements to reproduce the phenomenon. This factor also gives content to the operative technique, as it determines the operations to be carried out with the experimental system and their order to reproduce said phenomenon.

Selection and preparation of the biological sample: in correspondence with the requirement of the task, the specific biological object and the part of it (sample) that satisfy two requirements will be selected, the first: that it contains the biological structure involved in the solution of the task and the second: that its observation is possible. In addition, the preparation to which the sample must be subjected to better manifest the phenomenon to be reproduced or the structure to be observed, established by the above factors, will be determined. This determines the content of the operative technique in terms of the operational system that allows satisfying the demand expressed in the previous sentence.

Effect or characteristic that reveals the biological phenomenon or structure: biological phenomena are manifested through changes in the biological structure or in the functions that it performs; therefore, to notice them it is necessary to vary the conditions of the biological sample. For this, it is necessary to determine, firstly, what those conditions will be and, secondly, whether to observe the changes it is necessary to prepare several samples that are subjected to different conditions or a single sample is subjected to different conditions.

To change the conditions, additional technical means to those determined by the other factors may be needed and will be included in the observing system. With this, content is also given to the operative technique, since the operations to be followed during the observation or experimentation that allows obtaining the necessary information for the solution of the experimental task must be listed.

Data processing method: this factor determines the way in which the data will be collected (necessary information), depending on whether it is necessary to describe a structure (an observation in optimal conditions) or to compare two or more different states of a phenomenon. These states can be determined by the description of the effect of a phenomenon (observation of before and after) or the study of a sequence of states (observation of a series of states including the beginning and the end). All this will determine the amount and the way in which the observations should be made, specifies who solves the task and is reflected in the operative technique.

Given the way in which the factors determine the content of the components of the experiment design, it is very useful to present it in the form of a double-entry table, since the same factor gives content to more than one component. By the columns, the design components of the experiment are placed and by the rows the factors that determine them. The table consists of five rows and five columns.

For each specific experimental task that is solved and in correspondence with its conditions and demands, it is necessary to specify the factors that determine the components of the design of the experiment. This is why the second column has been enabled and is identified with the phrase: specification of the factors (CF), (see table 1). This is the chart available to the student. In it, there are twenty empty cells that are available to be filled as needed and thus design the experiment.

Table 1- Experiment Design Chart

FACTORES	Concreción de los factores	COMPONENTES		
		Sistema experimental	Sistema de observación	Técnica operatoria
Estructura a observar				
Fenómeno a reproducir				
Selección y preparación de la muestra biológica				
Efecto o característica que revela el fenómeno o la estructura biológica				
Forma de procesamiento de los datos				

To compose the design table of the experiment, the student must use the system of knowledge and skills that he possesses on tools, technical means, assembly techniques of biological preparations, as well as the specific competences of Biology, related to the application of said knowledge to problem solving and, in particular, experimental practical work (Ruíz et al., 1987).

For the blank cells that, according to the statement of the experimental task, must be filled, we agree with Coquidé et al. (1999, cited by Séré, 2002) that: It would lack, occasionally, to go further and strive to let students choose the level of observation depending on the underlying problem: body, organ, cell, molecule. The limitations due to the variability of living beings or the irreversibility of experiences should be left to the judgment of the students or, at least, duly discussed. (p.361)

As a didactic method of intervention, an experimental opening sequence was used, according to Domènech (2013), to facilitate gradual learning in the use of the experiment design box. In this regard, the following scientific hypothesis was considered: if an experimental opening sequence is applied to use the experiment design table as a learning strategy for solving qualitative experimental tasks in Biology, progressive advances will be obtained in the cognitive independence of the students to solve these tasks.

To inquire about the validity of the scientific hypothesis, the experiment design table was defined as an independent variable and the cognitive independence of the students to design experiments was defined as a dependent variable, using said table.

The system of experimental tasks in Biology consisted of 12 tasks. The tasks 2, 8, 11 and 12 of Molecular and Cellular Biology; 1, 3, 6, 7, 9 and 10 of Botany; 4 of Human Anatomy and Physiology and 5 of Microbiology. More tasks of Botany and Molecular and Cellular Biology were included because these are the subjects that start the curricular map of the career in the second and third semester.

The experimental opening sequence was structured considering that, depending on the complexity of the task and the degree of independence achieved by the students, some of the elements of the components and some of the factors can be given in the statement of the experimental task, to a greater or lesser extent, and the rest must be found in the design process of the experiment.

The more elements are in the statement, more closed is the task and vice versa. According to Domènech (2013), "the more open, the more investigative the practice and the greater the protagonism and the scientific exercise of the students and mobilizes different scientific skills such as building hypotheses, designing experiments or drawing conclusions" (p.252).

It is considered, furthermore, that the board in that students must act according the designing of the experiment it is to determine the components for each of the factors previously identifying how each factor is specified in correspondence with the conditions and the requirement of the given task. For that reason, the experimental opening sequence referred only to the factors and not to the components of the design of the experiment, the application of the first means the determination of the second.

The proposed experimental opening sequence is illustrated in Figure 1.

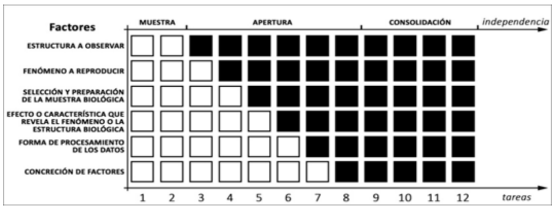

Fig. 1- Experimental opening sequence for the experiment design box

The intervention was divided into three phases: sample, opening and consolidation. In Figure 1, the unfilled boxes represent the sample and those that are fully colored, the opening and the consolidation.

In the sampling phase, the teacher offered the student how the given factor and its specification determine the components of the experiment design. The opening phase began when the student, for the first time, performed each of these actions independently. This phase extend from task 3 to 8 for each task, it is performed the opening of a factor and finally its realization. The sample and open phases overlapped; only the first two tasks were completely sampled. For different factors and their concretion, the sample phase continued until task 8, at the same time as other factors that were remaining open to the student.

The same happened with the consolidation phase; This began immediately after opening the given factor or its concretion, which occurred on Task 4 and it was completely established for all factors and their realization, for the entire table design the experiment, it from the task 9. With the opening sequence, it will guarantee a gradual transition from the phase sample to the consolidation.

It is necessary to consider that consolidation occurred differently for each student; therefore, the teacher's help in the process of gradual transition from dependence to independence was different for each student.

During the intervention, it was carried out or qualitative assessment of the performance of the student conform to the design of the experiment each solved task. In the tasks 9 and 12, it was given to each student a score for each factor and its realization; with these qualifications, an statistical analysis from block design complete to chance (Ochoa, 2014) that assess the progress achieved in cognitive independence of students in the design of experiments was done. It was decided to designate with the term "test" the quantitative evaluation carried out in tasks 9 and 12 to avoid confusion with the qualitative evaluation carried out in all tasks.

In addition, after the solution of each task, as feedback, the open interview was applied to inquire about the motivation of the students towards the use of the design table of the experiment, as well as the technique of the positive, the negative and how interesting.

10 students of the sample were characterized as having an average academic achievement. Although all passed the entrance exams to higher

education, they showed few study habits and never had faced the solution of experimental tasks required by the designing of the experiment. Only two students graduated from the intermediate level course for Biology-Chemistry teachers had carried out laboratory practices in a systematic way, but following the traditional style of a reproductive guide with steps ordered to be executed. The above information was obtained from the pedagogical delivery, the review of the student's file and the open interview, whose questions were directed to the following aspects: if they had previously carried out experimental practical work, how it had been and how often.

A randomized complete blocks statistical design was followed (Ochoa, 2014) composed of 6 varieties (5 factors from the design table and the specification of the factors) and 10 blocks (each of the students). The cognitive independence of each student was measured in the filling of each factor of the design table and its concretion. The results of the measurement were collected in a table of in which the cell $\mathbf{C_{ij}}$ contains the score of cognitive independence in the student **j** factor **i**. Measurements were made on an ordinal scale with the values 2 (bad), 3 (fair), 4 (good) and 5 (excellent) and were taken as data to perform hypothesis tests.

The specific objectives to assess the development of cognitive independence in the design of experiments were the following:

1. Compare the factors of the design table and their concreteness with each other, with respect to the achievement of the cognitive independence of the students when determining the components of the design of the experiment.

2. Establish homogeneous groups for the factors of the design table and their concretion, determined by the differences found in the first objective, with the purpose of designing didactic actions in the work with the factors of the design table and their concretion according to the homogeneous group in which they are located.

3. Compare the students with each other with respect to the achievement of the cognitive independence achieved when working with the design table of the experiment to draw a strategy of attention to the individual differences of the students.

The hypotheses to meet the first objective were:

H0: There are no differences in the cognitive independence of the students, between the factors of the design table and its concretion.

H1: There are differences in the cognitive independence of the students, between the factors of the design box and its concretion or, at least, there is a difference in one of them.

To test these hypotheses, to the factors of the design table and its concretion: structure to be observed, phenomenon to be reproduced, selection and preparation of the biological sample, effect or characteristic that reveals the phenomenon or the biological structure, form of data processing and specification of the factors.

For the second objective, the hypotheses were:

H0: The factors of the design box and its concretion belong to the same homogeneous group (there are no differences between the cognitive independence of the students, when working with the factors of the design box of the experiment and its concretion, belonging to the same homogeneous group).

H1: The factors of the design table and their concretion belong to different homogeneous groups (there are differences between the cognitive independence of the students, when working with the factors of the design table of the experiment and their concretion, belonging to different homogeneous groups).

To test these hypotheses, it was used the test of Duncan who divided the factors table design the experiment and its realization in homogeneous groups according to the average of the cognitive independence of students in the factor table design or realization corresponding.

For the third objective, the hypotheses were:

H0: There are no differences between the students in terms of cognitive independence, working with the design table of the experiment.

H1: There are differences between the students or, at least, there is a difference in one of them, in terms of cognitive independence, when working with the design table of the experiment.

To test these hypotheses, the same test is used as for the first objective. In this case, the fixed factor is each student labeled 1 to 10. The significance level for all statistical tests was á = 0.05.

RESULTS

The presentation and analysis of the design table of the experiment with the students was carried out in a 90-minute class session. The experiment design chart (table 1) was presented to the students and its structure was explained. At the same meeting class, the experimental task 1 was presented and discussed with students how to design an experiment that would arrive at the solution, using Table 1. The proposed student and address of the teacher, is they were completing those blank cells in table 1, necessary to make up the solution. For each proposal, the student was asked to argue their inclusion and location in the specific cell.

Through the evaluation of the students' performance, it was found that, in the sample stage, the greatest difficulties were specified in the insecurity to propose the content of the cells of the design table of the experiment.

In the experimental design of the first tasks corresponding to the opening, was observed a marked tendency to execution, manifested in include the same elements used previously by the teacher in other tasks resolved in the stage shown. When asked about it, they usually could not identify the function of what was proposed for the experiment that was being designed.

To overcome this difficulty, it was necessary to discuss with the students aspects, not only of biological content, but also of a didactic and logical nature. At all times, during the sample phase and until consolidation was achieved, questions were used to serve as a guide for the design of the experiment.

As an example, a part of the dialogue among the teacher (D) and some students (E) when designing an experiment for task 3, it is transcribed below:

D: Why will you use a microscope?

E1: To observe the cells.

D: But what are you going to observe of the cell?

E1: Its structure.

D: which cells are you going to observe?

E2: Those of the leaves and the stem of a plant.

D: Will it be sufficient just cells from the leaves and stem?

E1: Well, you can use the one with the flowers.

E9: Leaves, stems or flowers of different plants can be observed.

These guided questions were of great help during the solution of the tasks in which the opening took place and the consolidation began.

In the discussions, some of the students stated that the procedure to complete the design chart of the experiment was complex since they were facing it for the first time, that it was easier for them to carry out the laboratory practice with a structured guide where they should follow the steps already established by the teacher. Others recognized that they had to work hard to achieve the design; they considered that it was a challenge for them, that it motivated them to think and find novel solutions.

For task 3, related to the observation of the structural variety of the tissues of a plant, two working sessions were needed, given its complexity and the multiple ways in which the experiment could be designed. For this reason, group discussions were incorporated at the end to discuss the results achieved, using different designs of the experiment. This contributed to the students acting in a more conscious way, since in the final debates it was required to present arguments about each part of the experimental design carried out.

At the height of the solution of task 5, the students already showed greater independence, made the selection of instruments, prepared the samples and other elements of the experiment design table, in correspondence with the content of the task presented and the solution that this required, they used their previous knowledge in a creative way and looked for information to be able to complete the table independently. Motivation increased considerably, the students were enthusiastic about their achievements in the design of the experiment. They began to ask that the topic of each task be communicated to them in advance to delve into the biological contents of a theoretical nature necessary for the experimental design, in order to come better prepared. It should be noted that, although the topic of each task was made known to them in advance, the statement was not revealed to them to prevent them from bringing the experiment already designed, which would hinder the observation of the process by the researchers.

These results gradually consolidated the cognitive independence of the students in solving experimental tasks in Biology.

In order to quantitatively evaluate for the first time the cognitive independence achieved by the students in the work with the experiment design table, their results were scored in task 9 (first trial). Table 2 collects these ratings.

The test of the inter subject effects for the fixed factor: factors of the design table and its concretion yielded a significance of 0.000 <0.05, which indicates that there are highly significant differences in cognitive independence. That is to say, not for all the factors and their concretion has reached the same degree of cognitive independence.

Duncan's test for the determination of homogeneous groups for factors of the design table of the experiment and its concretion yields the formation of three significantly different groups. The first group (specification of the factors, effect or characteristic that reveals the phenomenon or the structure and selection and preparation of the biological sample) presents the worst averages between 2.20 and 2.40. In the second group, the form of data processing and the structure to be observed are located, with an average of 4.00 and 4.20 respectively. In the third group, the phenomenon to be reproduced is located and, again, the structure to be observed with averages of 4.60 and 4.20.

Table 2 - Cognitive independence of students in the first trial

Primer ensayo						
Factores	EO	FR	SPMB	ECRFE	FPD	CF
Est. 1	4	4	2	2	4	2
Est. 2	4	5	2	2	4	3
Est. 3	3	5	2	2	4	3
Est. 4	4	4	2	2	4	2
Est. 5	5	5	3	3	5	2
Est. 6	4	4	2	2	4	2
Est. 7	5	5	3	3	5	2
Est. 8	4	5	3	2	3	2
Est. 9	5	5	3	2	3	2
Est. 10	4	4	2	2	4	2

These results suggest the degree of difficulty presented by the factors and their concretion to be determined independently by the students with whom the intervention was carried out.

With the first group, it was decided to redesign and intensify the didactic actions, because they were the most affected. With groups 2 and 3, it decided to continue applying of the teaching activities previously designed.

The first action consisted of reinforcing the work with the first group of factors from the design table of the experiment, through guided questions and discussing the results achieved in the designs made by the students to illustrate the various variants and draw attention to the errors more frequent.

The test of the inter subject effects for the fixed factor: student reached a significance value of 0.008 <0.05, which indicates that the statistician falls in the rejection zone and reveals that there are significant differences between the students.

The analysis of the averages per student showed values in the closed interval from 2.17 to 3.83. Based on these results, the second didactic action was drawn for tasks 10 and 11: to intensify individualized attention to each student according to the factor in which they presented a difficulty. It was also worked intensively with students: 8, 3, 10, 6, 4 and 1 which had the worst averages in that order. With these students, weekly consultations were planned with differentiated attention according to the difficulty presented.

As a final result of the first trial, it was concluded that there were significant differences in cognitive independence in working with the design box of the experiment, both among the students and between the factors of the design box and its concretion.

At the end of the intervention, the second trial was carried out with the same objective as the first to assess possible advances or setbacks. This corresponded to task 12 (final). The data obtained are shown in table 3.

Table 3- Cognitive independence of students in the second trial

Segundo ensayo						
Factores	EO	FR	SPMB	ECRFE	FPD	CF
Est. 1	5	4	5	4	4	4
Est. 2	4	5	4	5	5	4
Est. 3	3	5	4	5	4	4
Est. 4	4	4	4	4	5	4
Est. 5	5	5	5	5	5	5
Est. 6	5	4	4	4	4	4
Est. 7	5	5	5	5	5	5
Est. 8	5	5	5	4	4	4
Est. 9	5	5	4	4	4	4
Est. 10	4	4	3	3	3	4

The test of the inter subject effects for the fixed factor: factors of the design table of the experiment and its concretion yielded a significance of 0.751> 0.05, which indicates that H0 is not rejected and means that there are no significant differences in cognitive independence, in the work with the factors of the design table and its concretion.

The Duncan test does not throw the formation of different groups, which is logical, in the absence of significant differences in cognitive independence in working with the factors of the box design and realization. Furthermore, the means of cognitive independence, in all cases, are above 4.30.

From the didactic point of view, these results are favorable for what was considered as an indicator of the achievement of cognitive independence in the design of the experiment. It is to say, it was considered that the students already dominates the procedure for working with the box design the experiment.

The inter subject effects test for the student fixed factor returned a significance value of 0.001 <0.05, indicating the existence of differences between students. However, in all cases, the results are favorable with respect to the first trial (see figure 2), so with this trial , it was decided to complete this phase of the investigation .

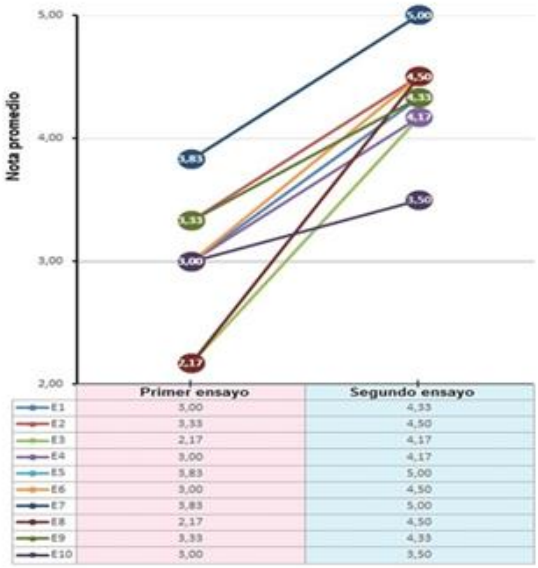

Fig. 2- Averages per student in the first and second trials.

The totalizing qualitative evaluation, for its part, evidenced the diversity of forms used by the students to fill the design box, especially in the part referring to the selection and preparation of biological samples, since they chose different samples and/or prepared them in different ways. Differences were also observed in the completeness of the information, since while some only noted a few relevant aspects, others made detailed descriptions. It was also observed that some students (especially 5 and 7 and, on some occasions, 9) proposed novel solutions, manifesting cognitive independence at a higher level.

Maintaining the motivation of students also found towards to the realization of the experimental tasks. This was also corroborated in the open interview, whose questions were directed to inquire about their motivation and the solution process.

In addition, it was found that, if the task involved phenomenon and structure, it was much more difficult for students to complete the table. Likewise, if the task required more than one sample, the students considered that the solution was too long and had doubts as to whether they should make a table for each sample or if they could put everything in one or only one. It was always made clear to them that, if the requirement of the task involved several samples, they were all in the same table and that the differences occurred in the operative technique and data processing.

At the end of each work experience, it is also applied the technique of the positive, negative and interesting. The students indicated as negative the difficulties to complete the table when applying the concepts of experimental system and observation system. To overcome this difficulty, the teacher began to write on the board, from the third task, the definitions of these concepts. After task 6, this difficulty decreased.

Also, as negative, students 8 and 10 stated that, to complete the table, they had to write, think and work more, so they preferred the practices with the reproductive guide. In this regard, the performance of the rest of the group was important, as they managed to engage these students, which is why their grades are good.

On the positive side, they stated that they felt capable of designing their own experiment and valued the painting as a didactic resource for their future professional work. The interesting thing pointed to the value of the box to guide and enable the design of the experiment individually.

DISCUSSION

During the inclusion of the design of the experiment within the teaching-learning process, some barriers were found in the students such as: the tendency to perform, the lack of arguments in the choice of design elements and the appreciation of design as a difficult process. The authors assume that the causes lie in the fact that the students had never faced the design of experiments independently.

The uncertainty in proposing the content of the cells of the design table of the experiment found in the sample stage can be explained by the fact that the student has never been faced with designing experiments independently. In secondary and pre-university education, the practices are carried out in the traditional way, through a guide, with the steps to follow, a "recipe" type (Carrascosa et al., 2006; Carp et al., 2012; Tenreiro & Marqués , 2006, cited in Domènech, 2013).

The marked tendency to execution, which was manifested in the completion of the table without a previous analysis, agrees with Crujeiras & Jiménez (2015), whose results showed that the student tries to solve the task by trial error, instead of planning a design. This highlighted the need to introduce questions that encourage the analysis by the student. (Domènech, 2013) (Crujeiras & Jiménez, 2015)

In some cases, it was necessary to spend more time than planned initially to the design of the experiment (as in task 3), and that, to the act in error test, the student spends much time proposing designs which must then be discarded. Similar results were obtained by Crujeiras & Jiménez (2015).

The gradual increase of the independence of students in the experimental design and the satisfactory results achieved in the second test coincides with the results obtained by Domenech (2013), who also uses a sequence of opening required for the design of experiments.

The independent design of experiments by students constitutes one of the current challenges in science teaching since the student "presents difficulties in relating the scientific content with the experiment to be carried out" Crujeiras & Jiménez (2015). A didactic resource such as the proposed table is very useful, both for the teacher and for the student. The first, lets you guide the work of the student and expose the logic of the design of the experiment and the second, makes it possible to capture on paper or computer design the experiment that otherwise may be a mental level.

To overcome the barriers detected, it was necessary to solve 12 tasks in which the students gradually faced the design process. The experimental opening sequence was a great help by combining teaching of the teacher through the samples and learning aid each time independent of the student in the opening and consolidation.

The randomized complete block design was useful to perform two evaluative cuts (two trials) from which didactic actions were drawn.

From the quantitative point of view, it was found that the greatest difficulties in the design of the experiment are in the specification of the factors, effect or characteristic that reveals the phenomenon or the structure and selection and preparation of the biological sample. Therefore, the teacher is recommended to decide to use the experiment design chart as a teaching resource and to develop specific teaching actions for this group of factors. It is also proposed to use guided questions during the opening and the transition to consolidation and to discuss the results at the end of the design with the group of students.

Also, from the quantitative point of view, it is detected differences among students in correspondence with the individual characteristics of their learning, which showed that different students need pedagogical differentiated attention and different times of training in the use of the box design. The detection of these differences can be useful from the didactic point of view to identify difficulties and draw individualized strategies.

Although in the intervention it was necessary to use 12 experimental tasks to achieve the desired cognitive independence, the number of tasks can vary depending on the particularities of each group of students.

The research carried out offered positive results on the validity of the scientific hypothesis, although it would be useful to apply the design table of the experiment in other subjects of the specialty, in the training of Biology teachers. It is also suggested to implement its teaching using an opening sequence analogous to that of this research to assess its variability.

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