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Secção 1: *Investigação em Educação em Ciências, Matemática e Tecnologia*

LEAVING NO ONE BEHIND: ACTIVE LEARNING REDUCES ACADEMIC GAPS IN A UNIVERSITY INTRODUCTORY BIOLOGY COURSE IN COLOMBIA

NÃO DEIXANDO NINGUÉM PARA TRÁS: APRENDIZAGEM ACTIVA REDUZ AS LACUNAS ACADÉMICAS NUM CURSO UNIVERSITÁRIO DE INTRODUÇÃO À BIOLOGIA NA COLÔMBIA

NADIE SE QUEDA ATRÁS: EL APRENDIZAJE ACTIVO REDUCE LAS BRECHAS ACADÉMICAS EN UN CURSO UNIVERSITARIO DE INTRODUCCIÓN A LA BIOLOGÍA EN COLOMBIA

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ABSTRACT | A global trend is transforming classroom traditional practices and adopting innovative pedagogical strategies that are supported by evidence, such as active learning. Nevertheless, few initiatives have been carried out in Latin America. This article presents the results of an evaluation of the impact of active learning on a general biology course on the academic performance of students, their differences in the level of their knowledge, and the degree of acceptance of the courses carried out in a university at Colombia. A segregation gap in knowledge was detected at the start of the course but the group, as a whole, was more homogeneous at the end. The results show a tendency to improve knowledge of the discipline as well as a homogenization in the appropriation of knowledge by students.

KEYWORDS: Active Learning, Biology teaching, Equity, Science Education, Higher education.

RESUMO | Uma tendência global é transformar as práticas de sala de aula tradicionais e adotar estratégias pedagógicas inovadoras que são apoiadas por evidências, como a aprendizagem ativa. No entanto, poucas iniciativas foram realizadas na América Latina. Este artigo apresenta os resultados de uma avaliação do impacto da aprendizagem ativa num curso de biologia geral sobre o desempenho académico dos alunos, as suas diferenças no nível dos seus conhecimentos, e o grau de aceitação dos cursos ministrados numa universidade da Colômbia. Uma lacuna de segregação no conhecimento foi detetada no início do curso, mas o grupo, como um todo, foi mais homogêneo no final. Os resultados mostram uma tendência para melhorar o conhecimento da disciplina, bem como uma homogeneização na apropriação do conhecimento pelos alunos.

PALAVRAS-CHAVE: Aprendizagem Ativa, Ensino de Biologia, Equidade, Educação em Ciências, Educação superior.

RESUMEN | Una tendencia mundial está transformando las prácticas de aula tradicionales y adoptando estrategias pedagógicas innovadoras respaldadas por pruebas, como el aprendizaje activo. Sin embargo, en América Latina se han documentado pocas prácticas de este tipo en la educación superior. Este artículo presenta los resultados de una evaluación del impacto del aprendizaje activo en un curso de biología general sobre el rendimiento académico de los estudiantes, sus diferencias en el nivel de sus conocimientos y el grado de aceptación de los cursos realizados en una universidad de Colombia. Se detectó una brecha de segregación en el conocimiento al inicio del curso, pero el conocimiento del grupo, en su conjunto, fue más homogéneo al final. Los resultados muestran una tendencia a mejorar el conocimiento de la disciplina, así como una homogenización en los conocimientos de los estudiantes.

KEYWORDS: Aprendizaje Activo, Enseñanza de la Biología, Equidad, Educación en Ciencias, Enseñanza Superior.

1. INTRODUCTION

The growing importance of science and technology in society, both from a productive point of view and from its relevance for training critical thinkers, has driven the permanent renewal of science education at different educational levels. Despite it, there are relatively high levels of disinterest and dropouts in professions related to science, technology, engineering, and mathematics. The blaming role of the first semester is unquestionable in which courses are generally approached through master classes for large groups; and they are considered difficult by students, generating disinterest, and contributing to dropouts (Canning et al., 2018; Wienhold & Branchaw, 2018). Therefore, innovative strategies are needed (OECD / ECLAC / CAF, 2016).

On the other hand, some challenges respect to improve higher educational programs and to build teaching practices that make real the educational equity have been pointed out: Keeping Higher Education programs in pace with the developments of science and of its interrelations (Meena & Naik, 2019) demands developing scientific skills and competencies, while addressing disciplinary content (Aikens, 2020; Armbruster et al., 2009; Hartikainen et al., 2019; Matsushita, 2018; Waniek & Nae, 2017); 2) Inclusion of groups that have traditionally been excluded from academia. Calls have been made to develop educational environments in which all students have equal opportunities to learn (Dewsbury & Brame, 2019). This implies considering the disadvantages that some students may have when starting their professional training or a particular course (Gegenheimer et al., 2017). For instance, women have been a specific target (Harackiewicz & Priniski, 2018, p. 410); 3) Low retention in undergraduate populations, especially for the first-year students has been a universal killer (Cottone & Yoon, 2020). For this reason, universities have been working to overhaul curricula and to design pedagogical strategies that counteract this trend. Main efforts have been focused on redesigning assessment tools, improving student attitudes, and self-efficacy beliefs, implementing active learning activities (debates, data analysis, problem solutions, etc.), establishing "cross-disciplinary connections, fostering higher-level problem-solving skills, among others (Cottone & Yoon, 2020).

In response, universities, especially in the United States and Europe, have been training their teachers and promoting programs that address specific problems such as the inclusion of students from underrepresented populations -like women, Latins, among others-, and dropouts in the first semesters in introductory courses in science and mathematics. For example, biology courses in the United States have been renewed with the formulation of the documents Vision and Change in Undergraduate Biology Education: A Call to Action (American Association for the Advancement of Science, 2009) and BIO2010 (National Research Council [NRC], 2003). Consequently, the approaches have moved from being focused on disciplinary content based on lectures, towards approaches that focus on the development of scientific skills and competencies focusing on learning, and the courses now include objectives such as reading the primary literature, developing and testing hypotheses, analyzing data using statistical methods, conducting authentic research experiments, thinking creatively and critically, working effectively in teams, and applying knowledge to novel situations (Goldey et al., 2012).

One particular and important problem is the differences in the basic training of students when they are admitted to university. In general, students have differences in your academic background that create gaps between them. Thoses gaps tend to increase during the first years; and, by not closing the gap, it causes these students to prefer to give up professions related with science and maths and opt for other fields of knowledge. When students with deficiencies in basic training obtain low results in their courses, it impacts their self-confidence, commitment, and interest (Harackiewicz et al., 2016). However, some studies have found that active learning could contribute to closing these gaps between students from underrepresented groups and other students (Theobald et al., 2020).

In the case of Colombia, academic factors are the main cause of leaving university studies (Rodriguez-Urrego, 2019). This situation contributes to the exclusion of underrepresented groups in academia, because it is these groups that generally have the lowest academic background (Barragán-Diaz & Patiño-Garzón, 2013). They generally come from rural areas, are part of Afro-colombians and indigenous communities (Meneses Pardo, 2011). In other words, they have some academic disadvantages respect to urban-middle- class students. In fact, nearly 80% of indigenous students fail to complete their university studies (Caicedo & Castillo, 2008), and the cumulative dropout for mathematics and natural sciences is 51% (Melo-Becerra et al., 2017). Thus, the difficulties these students face in achieving the performance of students with better basic academic knowledge, configures the university as an adverse and discriminatory environment (Protzko & Aronson, 2016), generating disinterest and leading to dropping out. To deal with this situation, it should be considered that traditional lecture strategies are not very effective for including all students, and the use of strategies such as active learning to strengthen the skills and knowledge of the whole group is recommended (Freeman et al., 2014). Of course, active learning is only one way to deal with a complex problem that implies to create inclusive educational policies that impact all school levels.

In the current case study, we addressed the following research questions: What impact does the use of active learning strategies have in reducing knowledge gaps among participating students? What are the students' perceptions of the course when active learning strategies are included?

2. THEORICAL FRAMEWORK

Active learning is a broad concept that encompasses various initiatives geared towards "involv[ing] students in doing things and thinking about the things they are doing" (Bonwell & Eison 1991, p. 2). Mizokami (2018) defines active learning as "all kinds of learning beyond the mere one-way transmission of knowledge in lecture-style classes (= passive learning). It requires engagement in activities (writing, discussion, and presentation) and externalizing cognitive processes in the activities" (p. 79). According to Bonwell and Eison (1991), active learning has the following characteristics: students are engaged in activities, the emphasis is placed on developing students' skills and students' attitudes and values; and students are involved in higher-order thinking skills.

Active learning implies the collaboration and interaction of students to foster discursive and argumentative skills. This approach emphasizes that students work with information, organize it, analyze it, and explain it to their peers (Armbruster et al., 2009). Thus, students are the center of the educational process, and a learning environment is generated that allows metacognitive development based on their being independent and critical thinkers (Bransford et al., 2000).

The different forms that active learning can take have been used; and how they affect different aspects of learning, such as retention in biology courses has been evaluated (Dyer &

Elsenpeter, 2018). In fact, some universities have developed curricula under the approach of problem-based learning (Matsushita, 2018), extending the principles of active learning not only to a course, but to the entire professional training process. In general, building educational environments based on active learning has positive results in education in general, and in the teaching and learning of biology in particular (Aikens, 2020).

Students have higher failure rates in the courses developed with traditional approaches based on lectures, compared to those that focus on active learning (Freeman et al., 2014; Haak et al., 2011). Additionally, the use of active learning correlates positively with the development of critical thinking skills (Aguilera et al., 2017), quantitative reasoning, and modeling (Aikens, 2020). Active learning is also associated with the improvement of the academic performance of students in biology courses and their attitudes towards these courses (Armbruster et al., 2009), and the inclusion of underrepresented groups in academic spaces (Eddy & Hogan, 2014). In summary, there is some consensus among the educational research community that it is important to develop activities that seek promote active learning.

Even active learning is not enough to face the science learning obstacles, teacher, researchers in science education, and institutions have started different initiatives to develop resources, courses, and materials that materialize active learning in the classrooms. The implementation of active learning requires changes in the institutions and in the continuous training processes of teachers, to build clear pedagogical knowledge that can be related to practice (Auerbach & Andrews, 2018). Nevertheless, relatively few research about active learning estrategies implementation in higher education classrooms have been carried out in Latin America (Fleder & Ide, 2015; Mora et al., 2021; Romero-Hall, 2021; Suárez, et al., 2022). By contrast, the Latin-American Laboratory for Assessment of the Quality of Education (2020) denotes that active learning is very important to qualified teaching practices and "to promote that promote both basic and complex thinking" (p. 21) in this region.

3. METHODOLOGY

The study was carried in a course with nearly 170 students and repeated three times during three semesters. For each course we had three modules: Genetics and Evolution, Cell and organismic Biology, and Ecology, as in Table 1. A description of each activity developed in the course is in the Supplementary Material 1.

Table 1. *Learning goals of the course.*

COURSE LEARNING GOALS		
	Disciplinary content goals	**Skills**
Evolution and genetics	Introduce and discuss evolution as a fundamental axis of biology, and the most important factor of this topic Analyze the historical development of genetics as a subdiscipline of science	Students will… Identify, analyze, synthesize and argue basic concepts of biology Describe the relationship between living things in evolutionary terms Explain biological phenomena in space-time sequences Understand the complex organization of living beings at different levels of organization and their relationship with the environment. Assess the importance of the manner in which scientific knowledge is generated in biology.
Cell and organismic biology	Provide the basic concepts of the cellular and organismic organization of the living beings.	
Ecology	Know and assimilate the basic concepts that describe and explain the structures, processes, and organization of ecological systems at their different levels of organization. Know and understand the network of interactions between technological, socio-economic activities and ecological systems.	

3.1 Study design and data collection

The study used a quantitative approach. An initial test was applied that consisted of six open questions on concepts of biology that students are expected to understand at the time of their entrance into the university (Supplementary material 2). The questions focused on the modules of the course. The test was validated by two expert professors in these subjects, who made recommendations on the clarity of the questions and their conceptual precision.

Once the course was finished, the same questionnaire was applied again, and some questions were also included to unveil the perception of the students about the structure of the course, the organization of the topics, the fulfillment of objectives, the promotion of their participation and the impact of the practical activities in each module. The initial and final tests were scored on a scale of 0 to 5. Zero was the lowest score given when the answer did not address any concept related to the question. Five was the highest score when a clear answer was offered containing relevant biological concepts and processes.

3.1.1 Participants

The study was carried in a course with nearly 170 college students and repeated three times during three semesters. The study was carried out with students who voluntary took the decision of participate. To recruit the participants, all students were informed about the goals and procedures of study, showing the relevance to improve the teaching practices. Finally, the following students decided to participate in the research: n= 20 for semester 1, n=43 for semester 2, and n= 28 for semester 3.

3.2 Data Analysis

Using the data obtained, descriptive statistical analysis and multivariate statistical models such as canonical analysis of populations were applied, with a program developed by Rodríguez (2012, personal communication), MANOVA, principal component analysis, discriminant and correspondence analysis were performed with PAST 3.14 (Hammer et al., 2001). This software is free, user-friendly, just as Excel, addresses multivariate tests, and has been variously updated during its life of more than 10 years.

Let's review the main statistical ideas that we use here. To know that a variable X affects another Y, one varies X and looks for effects in Y. If Y is insensible, we say: Y is independent from X. If Y varies, we compare its variation with that when X is absent. To decide that X affects Y in average, we compare the variation of Y when X is present under various treatments or values of X against that when it is absent. This comparison is made in ANOVA with an F-test that deals with variances under normality assumptions. When we have many variables that come from observations from reality, correlations exist and covariances appear. All this goes into a matrix of covariances that includes the variances which are covariances of a variable with itself. Matrices are studied in Linear Algebra and the whole theory is called linear modeling. In MANOVA the null hypothesis is that all variables have the same mean but observed differences are due to randomness which is generated by all that than is not controlled. To reject the null hypothesis is equivalent to decide that at least one pair of means is different. Under normality assumptions, this is done with a Wilks lambda, which detects inequality of means when it is small. This is contrary to an F-test that detects difference in means when it is large.

To reinforce the idea of initial segregation, one can use discriminant analysis, which looks for the perspective that best separates two subgroups.

Imagine now that we are describing the performance of persons in an exam. Usual tests collect information in which scores are assigned to each student in agreement with his or her performance for each question. Principal component analysis is a descriptive simplifying technique that compress the information producing informs like the following:

Let us assume that the class has two dominant and independent stereotypes. The first is Luisa that is bad for quantitative biology but is good dealing with interrelations in ecology. The second is Juan that is good for cell biology buy deficient in analysis of heredity and genetics. The generality of students has some part of Luisa and another of Juan. A minor fraction is divergent.

Correspondence analysis presents graphically over the plane the associations detected by a two-way contingency table. If the association of a row with a column is strong, they are represented near one to another in the plane. Increasing distance reflects a lack of association.

All this is very technical and the literature scares everybody. Nevertheless, the work by Mertler and Vannatta (2017) is excellent to join deep mathematics with common sense because every test has a section dedicated explaining its logic.

4. RESULTS

The proportion of dropouts was less than 5% on average, with 170 students each course, during the three semesters of intervention. Let recall that the cumulative dropout for mathematics and natural sciences is 51%. This result alone says that active learning is worth the effort. Ethical considerations prevent us from pursuing more comparisons with external sources and more discrimination of our students in diverse subgroups. A pitfall of this directive is that we cannot assess the effectiveness of our methodology to acquire knowledge and skills. All what follows refers to the same course in which for each semester we compare the initial state (of all students?) with the final one (of all students together?). The results from the test for each semester at the beginning and end of the course are presented below. The questions about the perceptions of the course were only implemented in the final test.

4.1 Semester 1 Results

4.1.1 Initial test results

With the 20 students who participated, an assignment was given in classes according to each student´s performance in the initial test. Three subgroups were formed: subgroup 1, with five students with the highest overall scores ($\bar{Y} = 4.2 \pm 0.07$); subgroup 2, with 10 individuals with an intermediate score ($\bar{Y} = 3.6 \pm 0.03$); and subgroup 3, with five students with a low score ($\bar{Y} = 3.0 \pm 0.13$).

Due to the non-normal distribution of the data, we transformed them using the logarithmic function to fulfill the assumption of normality. Once the data were normalized, parametric models were applied. The first thing that was sought was the establishment of subgroups for the assignment of each individual with which the pertinent discriminant functions were obtained. The results showed that 100% of the individuals were correctly classified in their respective subgroup.

Next, an attempt was made to establish whether the three subgroups were different from each other. To do this, a MANOVA was applied that registered a Wilks lambda of $\lambda = 0.01075$ ($p = 0.0254$), with which the difference in knowledge level between the three established subgroups was demonstrated. This is corroborated when obtaining the output of the canonical analysis of populations using the option of the most extreme individuals (Figure 1).

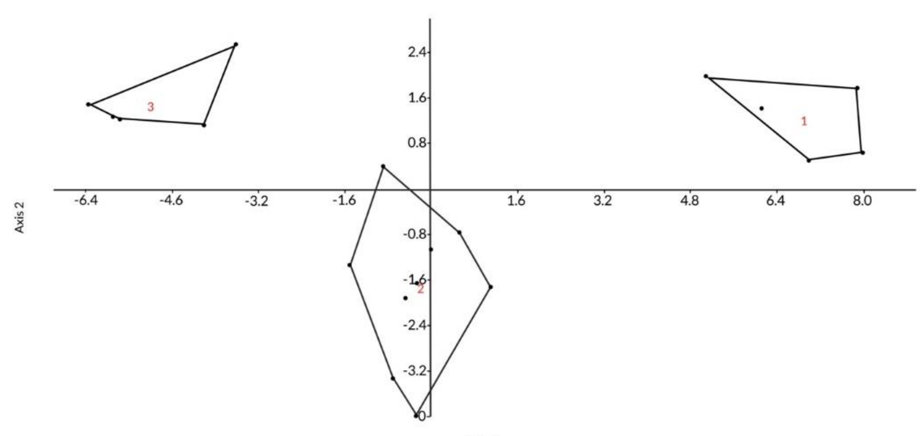

Figure 1. Spatial distribution for the three subgroups formed at the beginning of the course development in cohort 1 of the introductory biology course. The scores of students in a test given at the start of the course, which is also the start of semester 1, are naturally segregated in three subgroups. Principal component analysis says that the variation in score is due mainly to two prototypes or to two principal axes. The differences are so clear that the Wilks lambda renders them significant in spite of the few number of participants, which were 20.

4.1.2 Final questionnaire results

Once the course was finished, the grades showed improvement in knowledge, with certain differences between the course axes. It was clear that the sense of belonging to the established subgroups was diluted in 25% of the individuals. The remaining 75% remained well-classified.

This is associated with the results of the MANOVA that show a tendency to blur the differences that were registered at the beginning of the course, with a Wilks lambda of $\lambda = 0.48$, and an associated probability of $p = 0.5712$, a situation that is reflected in the output graph of the population analysis (Figure 2).

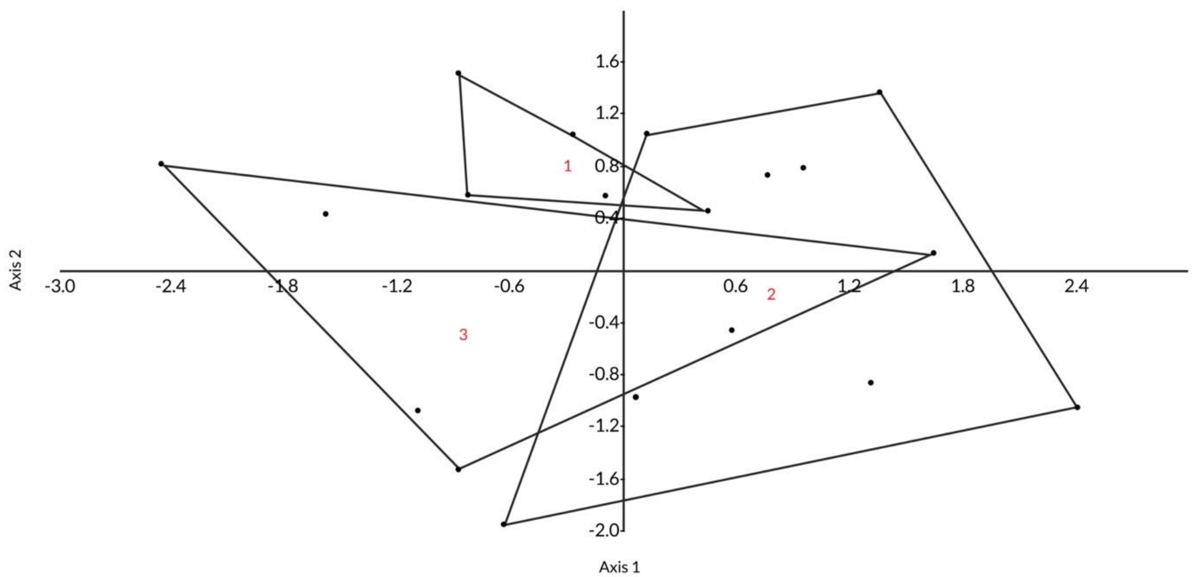

Figure 2**.** Spatial distribution for the three subgroups formed at the end of the course intervention in cohort 1 of the introductory biology course.

In order to establish the factorial structure of the data and verify the variables with the greatest impact, a principal components analysis was applied in which an explained variance of 71.4% was obtained with the first two components. Applying the Broken Stick graphical test the data were shown to be statistically different and therefore sufficient to explain the data. When obtaining the most relevant correlations of the questions with the components, the one with the highest correlation for the first component was one of the questions of the ecology module ($r = 0.93504$) in which most of the students were not able to respond. The next magnitude in correlation ($r = 0.63548$) was for the first question of the genetics module, in which most of the students answered correctly.

For the second component, a correlation ($r = 0.72017$) was recorded with the second ecology question, reflecting the difficulties in understanding the proposed concept.

4.1.3 Results of students' perception of the course

Questions about the structure and relevance of the course are reflected in the correspondence analysis between the variables that impact the students' grades once the course is completed, including the course structure (Course str), topic structure (Topics str), compliance of the course objectives (Object), student participation in modules one, two and three (Part M1, Part M2 and Part M3), realization and relevance of workshops in modules one, two and three (Workshops M1, Workshops M2 and Workshops M3). In the analysis, we found that the workshops of the evolution and genetics module ($\bar{Y}$ = 4.78 ± 0.53), as well as the participation of students in its classes ($\bar{Y}$ = 4.78 ± 0.45) were closely related to the individuals who participated in the test, together with the course structure ($\bar{Y}$ = 4.67 ± 0.69), topic structure ($\bar{Y}$ = 4.33 ± 0.61), the fulfillment of the objectives ($\bar{Y}$ = 4.22 ± 0.61). However, in module 3 both participation and workshops in module 3 were found to have little association (Figure 3).

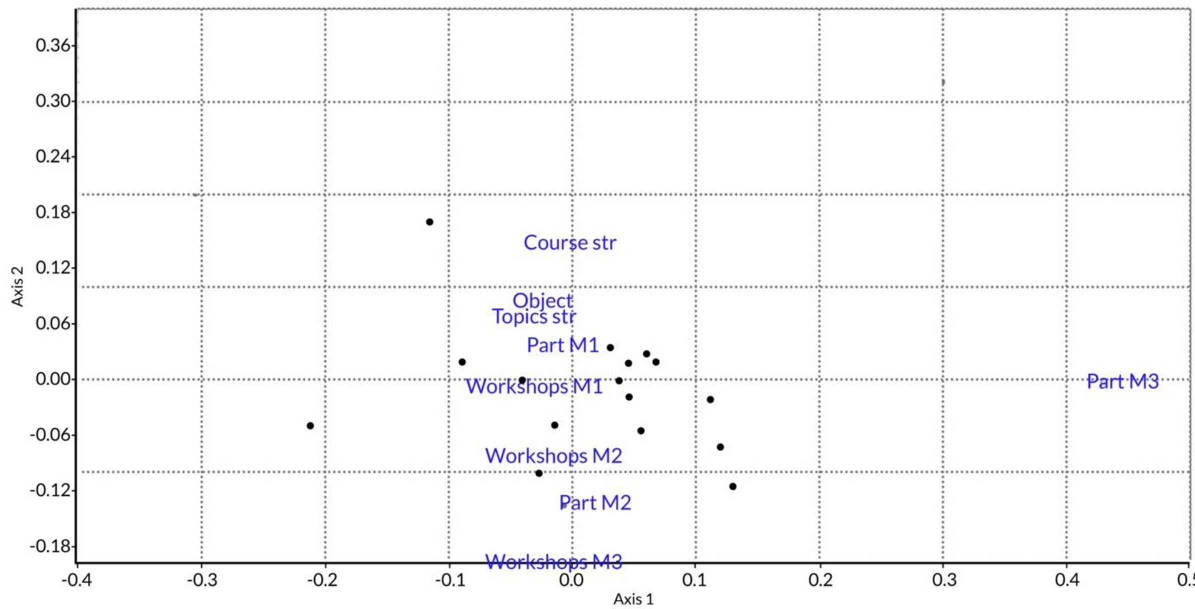

Figure 3. Correspondence analysis between the variables that affected the development of the curriculum at the end of the course intervention in cohort 1

4.2 Semester 2 Outcome

4.2.1 Initial diagnostic results

In the second group, 43 students participated, who were grouped, according to their performance in the initial diagnosis in four subgroups: subgroup 1 with six students with the highest overall scores ($\bar{Y}$ = 4.7 ± 0.242); subgroup 2 with 12 individuals with high scores ($\bar{Y}$ = 4.1 ± 0.054); subgroup 3 with 18 students with an intermediate score ($\bar{Y}$ = 3.4 ± 0.047); and subgroup 4 with seven students with a low score ($\bar{Y}$ = 2.7 ± 0.029). As in group 1, because of the non-adjustment of the data to a normal distribution, the groups were transformed using the logarithmic function; and, once this assumption was satisfied, the models were applied.

The tests for the classification of each individual to the assigned subgroup showed that 40 of the 43 participating individuals were well classified (93.02%) in their respective subgroups. The MANOVA showed that the four subgroups were different from each other, registering a Wilks lambda of λ = 0.0438 (p = 3.42x10--10) so that the differences in the knowledge of the four subgroups were highly significant, something that is reflected in the output of the canonical analysis of populations using the option of the most extreme individuals (Figure 4).

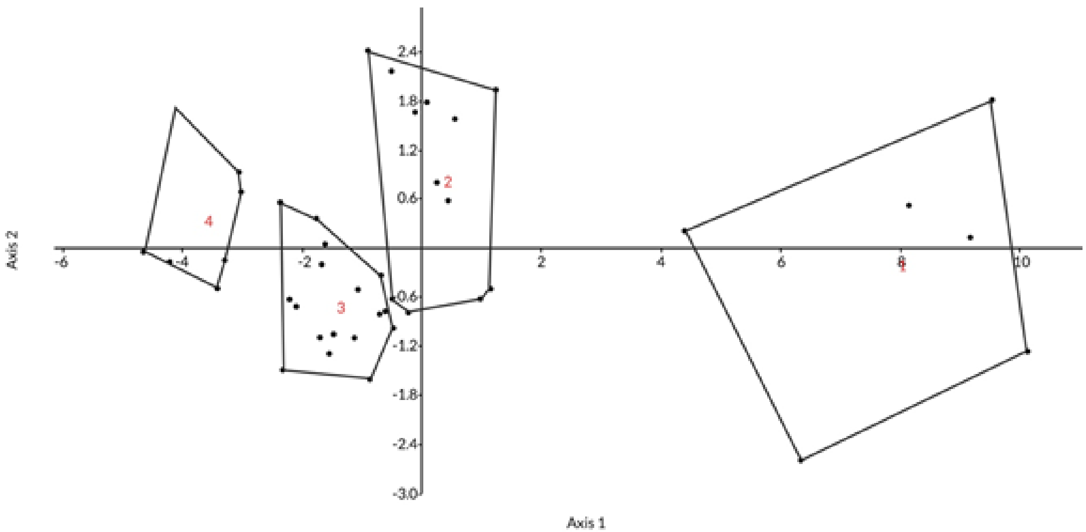

Figure 4. Spatial distribution for the four subgroups formed at the beginning of the course´s development in group two of the general biology course, second semester of 2016.

4.2.2 Semester 2 final questionnaire results

The evaluations of the final tests showed improvement at the beginning with a differential impact depending on the modules. Additionally, we found that the sense of belonging to the subgroups decreased to 69.05% of well-classified individuals. In this direction, the results of the MANOVA to establish the differences between the subgroups showed a tendency to reduce the differences in knowledge found at the beginning of the course with a Wilks lambda of $\lambda = 0.3057$, and an associated probability of $p = 0.00094$, a situation that is reflected in the graphical output of the population analysis (Figure 5). These results of the MANOVA show that there were differences between the subgroups, but that these only occur between subgroups one, two and three but not including subgroup four with a probability of $p < 0.004$.

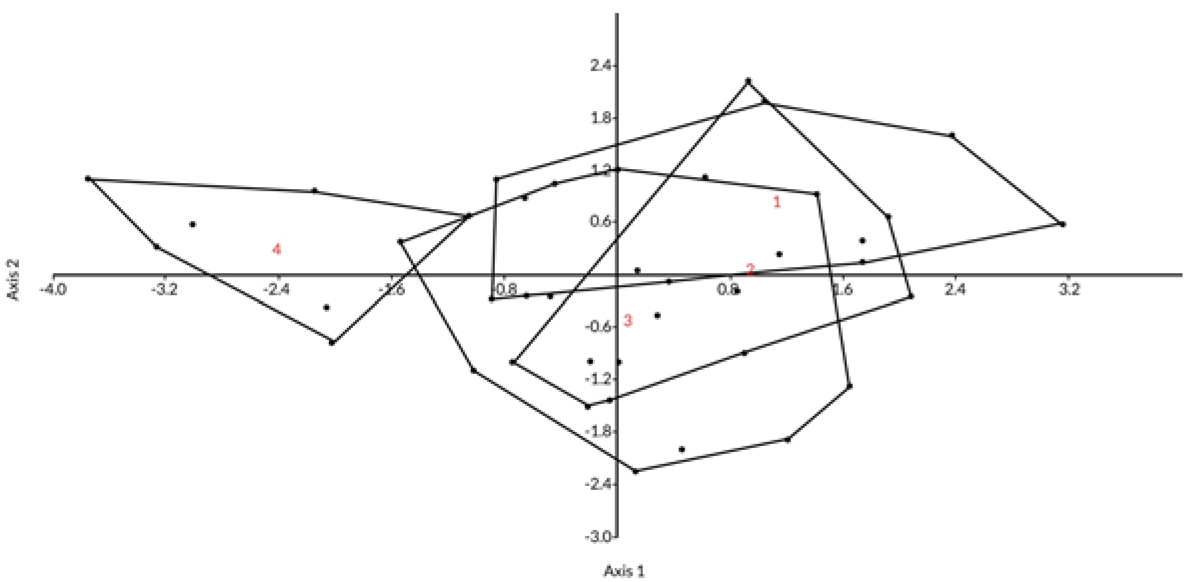

Figure 5. Spatial distribution for the four subgroups formed at the end of the course intervention in cohort 2.

Additionally, when applying the principal components analysis, an explained variance of 69.72% was obtained with the first two components, which with the Broken Stick graphic test proved to be statistically different and therefore sufficient to explain the data. When obtaining the most relevant correlations of the questions with these two components, the answer to the question with the highest correlation (r = 0.8363) was recorded for the first component corresponds to one of the questions of the module of cell biology and organismic biology. For the second component r = 0.7332 was obtained for one of the questions on evolution and genetics but in which they again recorded difficulties in the answers.

4.2.3 Analysis of the structure and relevance of the semester 2 course

When establishing associations between the questions about the structure and relevance of the course and the students, the correspondence analysis showed that between the variables that impact the curriculum and the grades of the students, once the course is finished there is an association between these grades with the structure in which the topics (Topics str), the course (Course str), the objectives (Object), the participation of modules one and two (Part M1 and Part M2), as well as the workshops of the first and third module are organized (Workshops M1 and Workshops M3), while the workshops carried out in the cell module (Workshops M2) and participation in the ecology module (Part M3) are the ones with the least association (Figure 6).

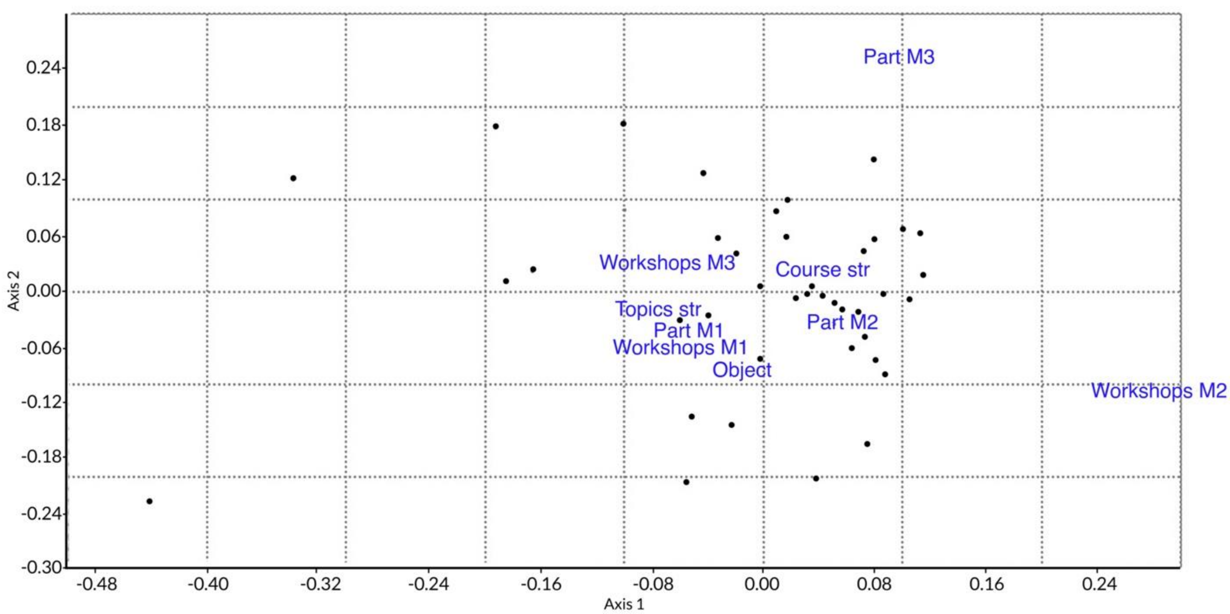

Figure 6. Correspondence analysis between the variables that affect the development of the curriculum and the grades of the students at the end of the course intervention in cohort 2.

4.3 Results from semester 3

4.3.1 Initial diagnostic results

This group included 28 students who were assigned to three subgroups: subgroup 1, with 9 students who obtained the highest score ($\bar{Y}$ = 4.7 ± 0.185); subgroup 2, with 12 individuals with an intermediate score (Ȳ = 3.4 ± 0.093); and subgroup 3, with seven students and a poor score (Ȳ = 2.4 ± 0.132).

As in the previous cohorts, due to the non-adjustment of the data to a normal distribution, these were transformed by means of the logarithmic function to fulfill the assumption of normality, and with this the parametric models were applied. The results of the association of each individual to the assigned subgroup showed that 25 of the 28 individuals (89.29%) were perfectly classified in their respective subgroup.

To establish the differences between the subgroups, a MANOVA was applied that recorded a Wilks lambda of λ = 0.1847 (p = 4.02x10--6). This showed elevated differences in the knowledge stock between the three established subgroups, corroborated by obtaining the output of the canonical analysis of populations using the option of the most extreme individuals (Figure 7).

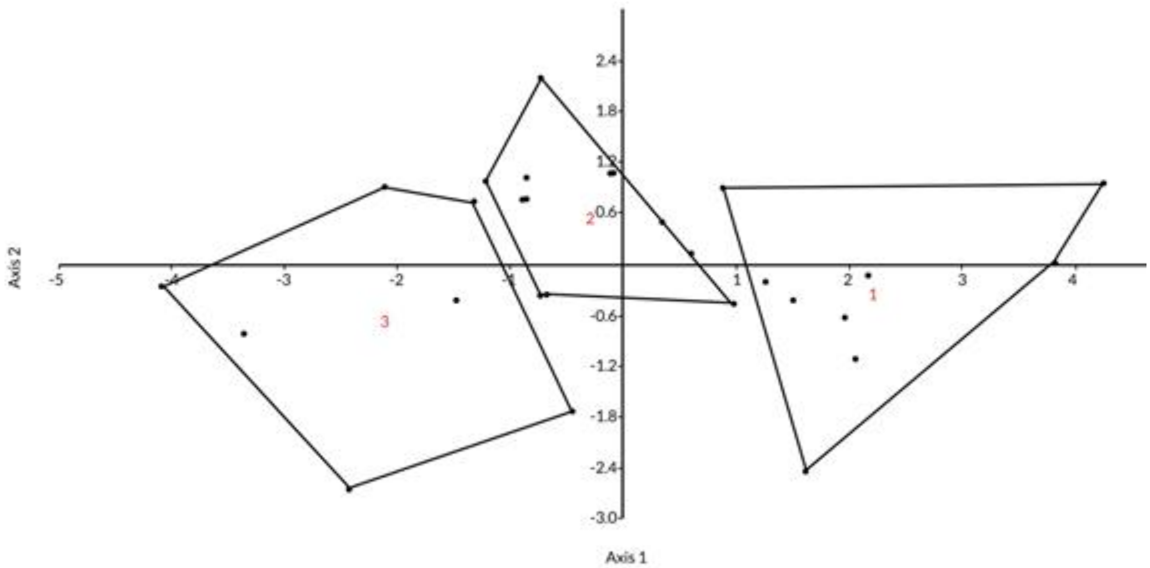

Figure 7. Spatial distribution for the three subgroups formed at the beginning of the course in group two of the general biology course, cohort 3.

4.3.2 Final test results

The final tests showed a behavior similar to that of semesters 1 and 2, finding better performances in the subgroups with respect to the initial test, with some nuances depending on the modules addressed. At the same time, the associations of the individuals with the subgroups were diluted to 35% of the individuals, the remaining 65% remained well-classified.

The results of the MANOVA showed a tendency to blur the very high statistical differences that were registered for knowledge in the biological sciences at the beginning of the course, with a Wilks lambda of λ = 0.406, and an associated probability of p = 0.065. This situation was reflected in the graphical output of the population analysis (Figure 8).

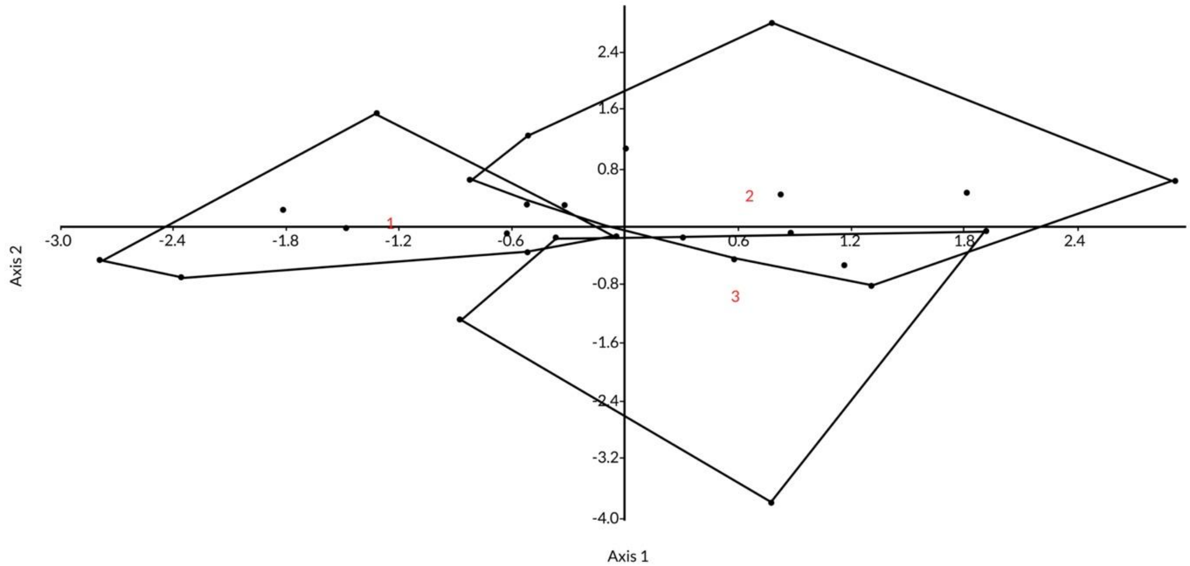

Figure 8. Spatial distribution for the three subgroups formed at the end of the course intervention in cohort 3.

When establishing the factorial structure of the data and verifying the variable(s) with the greatest impact in this study when applying a principal component analysis, an explained variance slightly higher than 79% was obtained with the first two components. Using the test Broken Stick graph proved to be statistically different and therefore sufficient to explain the data. When obtaining the most relevant correlations for the questions with the components, it was clear that the one with the highest correlation for the first component was one of the questions of the ecology module (r = 0.999558), which most of the students had problems answering.

For the second component, no significant correlations were recorded. This is why difficulties are inferred in identifying, extracting, and associating processes with their consequences within a biological phenomenon.

4.3.3 Analysis of the structure and relevance of semester 3

By establishing the associations with the correspondence analysis between the variables that impacted the curriculum with the student's grades once the course was completed, an association was recorded between the structure in which the course topics were organized (Topics str), the course structure (Course str), the objectives (Object), the participation of modules one and two (Part M1 and Part M2), as well as the workshops of the same modules (Workshops M1 and Workshops M2). These included the workshops carried out in module three, as well as participation in the same module as those that registered the least association (Figure 9).

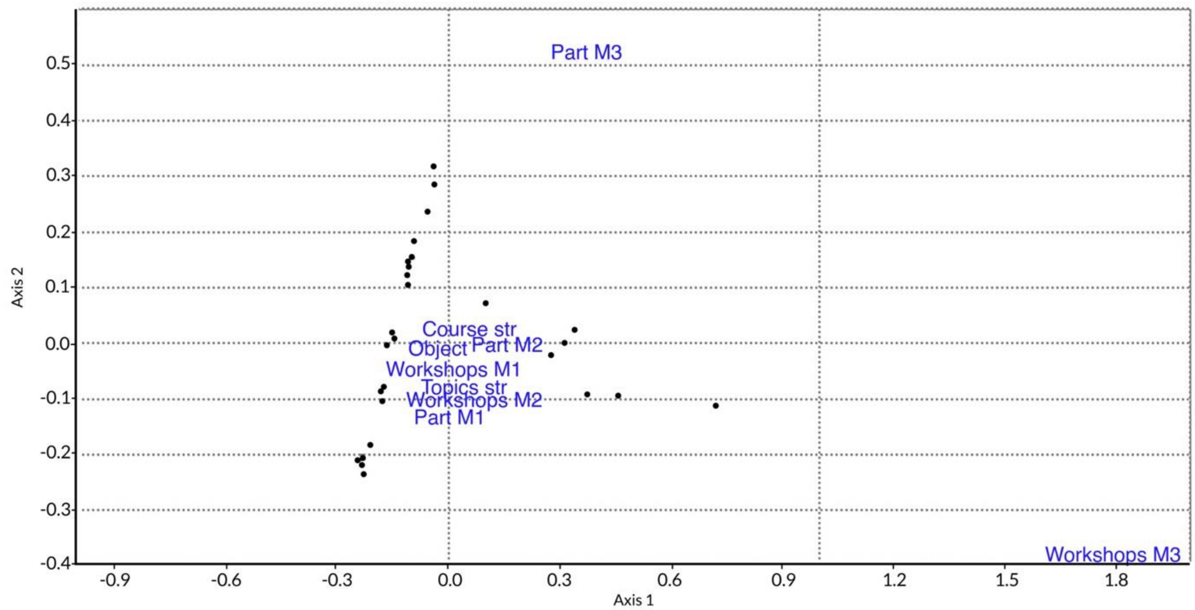

Figure 9. Correspondence analysis between the variables that affected the development of the curriculum and the students' grades at the end of the course intervention in cohort 3.

The workshops generated in the evolution and genetics module ($\bar{Y}$ = 4.59 ± 0.63), as well as the participation of students in the classes of the same module ($\bar{Y}$ = 4.54 ± 0.59), stood out with the best grades, while with lower grades the workshops ($\bar{Y}$ = 0.66 ± 0.13) and participation in the ecology module ($\bar{Y}$ = 2.18 ± 1.44) were recorded.

5. DISCUSSION

A growing body of research has shown that active learning is an effective strategy for increasing the levels of academic performance of students in higher education (Freeman et al., 2014; Haak et al., 2011; Hartikainen et al., 2019; Tal & Tsaushu, 2018). It has also been shown that the use of active learning in university classrooms allows academic performance to level off so that some students do not lag behind (Freeman et al., 2014; Haak et al., 2011; Rodenbusch et al., 2016). In general terms, the findings of our research converged with these approaches.

In the three modules studied, we found that there were differences in the knowledge of the students at the time of beginning the introductory biology course. Thus, according to their knowledge level, students could be grouped into subgroups that have statistically significant differences and that could cause lags and dropouts. These differences could be associated with social sectors that are traditionally underrepresented in academia (Caicedo & Castillo, 2008; Gegenheimer et al., 2017; Melo-Becerra et al., 2017; Meneses Pardo, 2011). So, in order to build a more inclusive university, initial courses should attempt to close these knowledge gaps so that all students remain in college.

After implementing introductory biology courses with an active learning approach, academic gaps were found to narrow. In module 1, at the end of the course, there were no statistical differences between the three subgroups, denoting a homogenization in the appropriation of knowledge, at the same time that they showed a global improvement in their performance when evaluating the topics of the course. In module 2, at the end of the course, two groupings were generated, one consisting of subgroups of the initial diagnosis one, two and three, in which the homogenization of the knowledge gained was evident, and the second group formed by subgroup four that showed a lower performance in the appropriation of knowledge. This case seemed to indicate the importance of making greater efforts for leveling performance, since subgroup 4 maintained its lag. It might be necessary to use academic support strategies such as those proposed by Gegenheimer et al. (2017). On the other hand, in module 3, at the end of the course, between the three subgroups no statistical differences were found. These results indicated that a good part of the students with low initial knowledge levels achieved similar performances to those of students with a better academic background at the beginning of the course. As a whole, the results showed a homogenization and improvement in the performance of the students.

The results seem to be consistent with the findings reported in other countries that highlight the usefulness of active learning for improving all student learning (Auerbach & Andrews, 2018; Freeman et al., 2014; Gegenheimer et al., 2017). It should be noted that the academic success of students during the first year was associated with a higher probability of graduating (Rodenbusch et al., 2016). So, although it was necessary to extend the studies, it could be suggested that active learning might contribute to changing the trends reported in Colombian universities (Barragán-Diaz & Patiño-Garzón, 2013; Melo-Becerra et al., 2017), in which initial courses are a factor that increases dropouts.

In the three modules studied, we found that performance was higher in the modules of evolution and genetics, and of cell and organismic biology compared to the module of ecology coinciding with the results reported in the evaluation of the students in the course, in which participation in the activities of module three were not well-qualified. This suggests the need to review the design of the activities in this module and to investigate in detail what are the academic difficulties that students encounter when addressing certain topics. Indeed, some authors have pointed out that although active learning is a key strategy in science education, not all topics could be adapted to it (Matsushita, 2018) and as Heinemann and Goldstien (2020) state, “How and how much active learning is used may need to be customized depending on the class, level of the student, instructor or subject matter" (p. 11). Therefore, the combination of strategies could, in some cases, be recommended. This implies a need to continue to investigate the specific contexts in which active learning is implemented.

Regarding the students’ perception of the course, a positive assessment was shown by the students. For example, the average for the course structure ($\bar{Y} = 4.6 \pm 0.69$) registered the highest value with respect to the other responses related to the program. This confirms the positive reception of the pedagogical proposal, which differs from the traditional manner of teaching that focuses on lectures, in which introductory biology courses have been developed. These results are relevant because it has been found that the use of active learning can be unpopular among students, since they perceive that this strategy implies investing more study time with respect to traditional lectures (Henderson et al, 2018). However, in this research the students did not report feeling uncomfortable with the focus of the activities.

The improved evaluation of the course by the course´s students could be explained by the fact that their academic performance improved and that the knowledge gaps between the established subgroups decreased. In some ways, this points to the importance of creating learning environments in which all students feel that they can improve their performance and promote their self-efficacy. As some studies have pointed out, one of the causes of dropping out and rejection of science and mathematics areas is the perception of the students leading them to believe that they will not be successful in these fields.

Finally, it should be noted that our research did not specifically inquire about the development of skills, interest, and attitudes; aspects that are important when evaluating science learning and that have been evaluated in the implementation of active learning in university classrooms (Felege & Ralph, 2019). That is an important limitation of this study, and an opportunity for research, assessing the development of attitudes and skills in science university courses.

6. CONCLUSIONS

The multivariate analyses applied in this research showed their robust and consistent relevance, by addressing both the sense of the students belonging to the groups within each module, the differences between the groups in the modules, and at the same time that focused on the most relevant measured variables in the study, establishing the associations that occurred in it.

In the three modules studied, significant statistical differences were obtained between the subgroups formed at the beginning of each course. These demonstrated the heterogeneity in the training process prior to entering the University. In general, at the end of the intervention in the modules, there was a tendency to improve knowledge of the discipline as well as a homogenization in the appropriation of knowledge.

There are differences between the results for the performance and the internalization of knowledge in biology between the modules of each intervened group, in which the modules of evolution and genetics, and cell and organismic biology showed, on average, the best results.

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