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Teaching food biotechnology in a university engineering program: blended and in-person approaches in Ecuador

Ensino de biotecnologia alimentar em um curso de engenharia através de sistema presencial e híbrido no Equador

La enseñanza de la Biotecnología alimentaria en una carrera de ingeniería mediante sistema presencial e híbrido en Ecuador

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Blended and in-person learning strategies
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The study highlights the potential benefits of implementing blended educational approaches, combining in-person and online instruction, to enhance learning outcomes in biotechnological education, offering valuable insights for educational policymakers and practitioners seeking to optimize teaching strategies
Originality/value:
The main value of the article is to present original empirical evidence, thus enriching the discourse on innovative pedagogical approaches in an educational field as important for Ecuador as biotechnology.

ABSTRACT

Food biotechnology is a modern science that generates interesting goods and services for society, it is part of the curriculum of agribusiness engineering careers in Ecuadorian universities. The objective was to determine the influence of the teaching system (in-person and blended) on learning levels. The sample consisted of four hundred students of the fifth level of the aforementioned career, divided into 8 different academic semester periods, during 4 consecutive years (2018, 2019, 2020, and 2021), four in an in-person system and four in a blended system (in-person and online) of an Ecuadorian public university, through a quasi-experimental type of research. The evaluation was carried out using both the grade records obtained by the students, as well as the application of a theoretical and practical test at the end of the course. The data were analyzed using descriptive statistics and a Student's t-test ($P \leq 0.05$). It was found that the in-person education system allows 72 % of learning of Biotechnology knowledge while the blended system improves it by up to 86 % with statistical differences between them, so Biotechnology is better understood and applied through a blended system of education.

Keywords: Biotechnology, blended education, in-person learning, engineering, agribusiness.

RESUMO

A biotecnologia alimentar é uma ciência moderna que gera bens e serviços interessantes para a sociedade e faz parte do currículo das carreiras de engenharia do agronegócio na universidade equatoriana. O objetivo foi determinar a influência do sistema de ensino (presencial e híbrido) nos níveis de aprendizagem. A amostra foi de quatrocentos alunos do quinto nível da referida carreira, divididos em 8 períodos letivos semestrais distintos, durante 4 anos consecutivos (2018, 2019, 2020 e 2021), quatro em regime presencial e quatro em regime presencial. sistema híbrido (presencial e on-line) de uma universidade pública equatoriana, por meio de pesquisa quase experimental. A avaliação foi realizada tanto pelas notas obtidas pelos alunos, como pela aplicação de uma prova teórica e prática ao final do curso. Os dados foram analisados por meio de estatística descritiva e teste t de Student ($P \leq 0,05$). Verificou-se que o sistema de ensino presencial permite 72% de aprendizagem do conhecimento da Biotecnologia enquanto o sistema híbrido o melhora em até 86% com diferenças estatísticas entre eles, portanto a Biotecnologia é melhor compreendida e aplicada através de um sistema de ensino híbrido.

Palavras-chave: biotecnologia, educação híbrida, sistema presencial, engenharia, agronegócio.

RESUMEN

La biotecnología alimentaria es una ciencia moderna que genera interesantes bienes y servicios para la sociedad, es parte del pénsum de estudios de las carreras de ingeniería en agroindustria en la universidad ecuatoriana. El objetivo fue determinar la influencia del sistema de enseñanza (Presencial e híbrido) sobre los niveles de aprendizaje. La muestra fueron cuatrocientos alumnos del quinto nivel de la carrera citada, divididos en 8 periodos académicos semestrales distintos, durante 4 años consecutivos (2018, 2019, 2020 y 2021), cuatro en sistema presencial y cuatro en sistema híbrido (presencial y en línea) de una universidad pública ecuatoriana, mediante una investigación de tipo cuasi experimental. La evaluación se realizó utilizando tanto el récord de calificaciones obtenido por los estudiantes, así como mediante la aplicación de una prueba teórico y práctico al finalizar el curso. Los datos se analizaron mediante estadística descriptica y una prueba de t de student ($P \leq 0,05$). Se encontró que el sistema de educación presencial permite un 72 % de aprendizaje de los conocimientos de la Biotecnología mientras que el sistema híbrido lo mejora hasta el 86 % con diferencias estadísticas entre ellos, por lo que la Biotecnología es mejor comprendida y aplicada mediante un sistema híbrido de educación.

Palabras clave: Biotecnología, educación híbrida, sistema presencial, ingeniería, agroindustria.

INTRODUCTION

This paper seeks answers to the following research questions:

1. In the Ecuadorian context, which of the two educational systems in question is the best to achieve an efficient learning of food biotechnology in the agribusiness engineering career?
2. What are the determining factors to achieve a high level of learning of food biotechnology in students of agroindustry in Ecuador? Does the educational system play a role?
3. Is it possible to improve the learning of Food Biotechnology by innovating the "online" educational system that was created by emergency in the COVID-19 pandemic?

The mission of the agro-industrial engineering career at the Ecuadorian university is to train agro-industrial engineers with solid, creative, integral knowledge, values and principles, identified with the local, regional, national and international reality, to direct, research and innovate agroindustry; respectful of the environment, with emphasis on security, sovereignty and food and non-food safety, in accordance with the productive matrix and the National Plan of Good Living of Ecuador. To achieve this, it uses a curriculum consisting of 9 levels (PAOS), where 60 subjects are taught in 6480 hours of work grouping in-person classes, independent work, experiential learning, pre-professional practices and curricular integration project or thesis. Food Biotechnology is taught in the sixth level of the career, it is considered a professionalizing science, it has an hourly intensity of 5 hours per week with 16 weeks of work per academic period (PAO), traditionally it was taught in a in-person manner, but due to the COVID-19 pandemic, the modality was changed to a blended system (part in-person and part online via internet), Thanks to this unforeseen event, the teacher had to implement a series of changes and migrate all the contents and activities to a Moodle virtual platform with a virtual classroom in an Oasis system and the Teams tool for the delivery of virtual classes, including laboratory practices through video tutorials. In this context, there were two different scenarios (in-person and blended mode) with different results, so the problem to be solved with this research work is to determine which of the two systems or educational modalities offers better results to establish the knowledge of food biotechnology in the students of this engineering career. Therefore, these objectives were proposed:

1. To evaluate the learning level of Food Biotechnology in Agribusiness Engineering students with two educational systems: classroom and blended.
2. Determine the advantages and disadvantages of each of the educational systems evaluated in the Ecuadorian environment.
3. Identify concrete actions to be implemented to improve the learning of food biotechnology in Agro-industrial Engineering careers in Ecuador.

The execution of this work is fully justified based on the following considerations:

Biotechnology as a science and as a subject of this engineering degree has great importance and technological applications to ensure food security for human beings.

It is necessary to determine the impact and influence of the educational system or modality on the level of learning of this science in engineering students, future agribusiness engineers.

It is clear that each educational modality has both advantages and disadvantages in relation to the level of learning of Biotechnology, and these should be highlighted and taken advantage of by the higher education system.

At the end of the study, alternatives could be proposed for the improvement of the educational system in order to achieve a better level of learning of Biotechnology and other related sciences.

Therefore, this work is a real contribution to the improvement of engineering education in Ecuadorian universities.

BIOTECHNOLOGY IN THE FIELD OF HIGHER EDUCATION

When human beings became sedentary, they developed the cultivation of plants and the care of animals for food. He then saw the need to preserve them and discovered that in some cases the food was modified and transformed into products that were not only stable, but were also pleasant to the taste and did not make them sick. It is thought that this is how the processes to produce fermented foods began to be "domesticated", foods that came to provide an important nutritional variety to the diet, at the same time that yeast, fungi and bacteria were empirically incorporated to the task of food production, thus initiating food biotechnology (Wacher, 2014). In order to achieve sustainable development, biotechnology is presented as an effective tool that allows different solutions to problems such as loss of agricultural productivity, pollution, new pests, diseases, reduction of green areas and biodiversity, through the application of innovative technologies, while

creating numerous business opportunities, through the transfer of knowledge which is carried out through formal agreements between companies and universities, or through the establishment of new companies dedicated to biotechnology founded by entrepreneurial academics (González, *et al*. 2010).

On the other hand, according to Perez (2022), as a result of the social distancing caused by the COVID-19 pandemic, blended education has emerged, which is booming alongside new educational technologies. Blended classes are a new option for the educational community. This blended model allows for the combination of a in-person portion with a distance, online portion that takes place in students' homes or workplaces mediated by technologies. Blended education is an alternative teaching method that emerged with the advance of educational technologies, presenting a new option for learning: blended classes. It is a model that combines Distance Education (DE) and in-person meetings. Initially, its objective was to solve the problems of time and distance for those who could not incorporate study into their daily routine or were too far away from the educational institution to attend classes. Gradually, however, people realized that blended education has other advantages for both students and teachers.

According to Dakhi, Jama & Irfan (2020) when we talk about blended classes we refer to an educational method that combines online and in-person education, taking advantage of the positive aspects of each and increasing the efficiency of learning. This type of teaching can be delivered in two ways:

Disruptive model

In this case, an ODL platform is used that offers video classes and allows students to access from anywhere. There may also be in-person meetings with professors to discuss a topic, carry out a special activity or make an evaluation. But this type of meeting is occasional and infrequent.

Semi-attendance model

Many institutions adopt this model that retains in-person classes, but with distance learning options.

Among the blended learning options, the following stand out:

Synchronous blended model

Synchronous means "at the same time", so the idea is to combine in a single class the physical presence of some students with the online participation of others. There can be rotation between groups or remain the same throughout the course. This model has been adopted in some schools and higher education institutions as a way out of the restriction of the number of students per classroom, or as an option to include more people.

Seasonal rotation model

The classes are divided into work stations, each of which has a specific function that together achieve a single objective. In the station rotation model, each student (or group) works in one space for a certain amount of time, and then moves on to another until all stations are completed throughout the process. As it is a blended education model, at least one of these stations must be online.

Rotational laboratory model

In this case, the working group is divided in two, according to the activity: theoretical or practical. After a while, they reverse their roles with the objective of reaching the same results, regardless of the order. A good example of this model is physical education classes, since knowing the theory of a game and its rules is as important as learning the techniques and having the experience of how those rules work. Thus, in one class there may be one group of students learning the theory of handball while the other is practicing it, and in the next meeting the opposite.

Individual rotation model

In the individual rotation model, students work individually, without having to go through all the study stations. In this way, the trajectory is personalized, according to the needs of each person. For example: if you are taking a course in electromechanics, you can opt only for the areas that are geared towards electricity.

Inverted class

The inverted class is a method widely used in universities. The student studies the subject that will be addressed, before the in-person classes. In this way, he/she is more prepared when the professor exposes the ideas of the studied subject. The professor, in turn, tries to ask some assumptions of the content, observes if they are correct or not and always contrasts them with a different idea within the material that the students read. In addition, the exchange of experience with the discussion of content seen before class is excellent for the learner to develop autonomy and a different way of thinking when obtaining their knowledge. In this way, the learner can choose his or her own way of learning.

Advantages of blended education

In any of these models, it can be said that the online medium gives students autonomy and flexibility, as well as allowing them to learn on their own and explore their capabilities outside the classroom. On the other hand, in-person meetings favor a more personal exchange of experiences and real-time communication. In other words, the two complement each other to enhance the teaching and learning process, in addition to broadening the audience for a given course. These are the advantages:

For students

Cultivating autonomy

Some people get used to studying alone and even prefer it, as they concentrate better. Blended education stimulates the ability to investigate and search for answers and solutions autonomously. This characteristic is excellent not only for studies but also for life, because it encourages the person to take responsibility for his or her decisions.

Enhancing learning

It is possible for students to learn even more by having continuous access to other types of materials suggested or not by the teachers. Thus, in-person meetings allow students to observe the subject they are studying in their own way.

To have greater flexibility

With blended classes, students can organize their study time in the best way, depending on their personal or family routine. Blended education overcomes in-person and time limits, since it is possible to study from anywhere and at any time.

Better use of classes

It is easy to observe that students can take more advantage of the classes because they do not stay only in the expository classes, but they seek knowledge before. In this way, it is possible for the student to learn even more, because in addition to what the teacher presents, he/she will have continuous access to other types of materials suggested or not by the teacher. In addition, the discussion that takes place afterwards, allows the student to try to observe in his own way the subject he is studying.

Approximation of the school reality

In addition to the two advantages presented in the previous topics, students can still organize their studies in the way that best fits their reality. That is, they manage to fit the study period into their daily life. It is not necessary just to go to a classroom to hear the teacher speak and finish the learning process there. Blended education overcomes these limits, since it is possible to study from anywhere and at any time.

For the institution

Making the most of work time

Not only do students benefit, but educators also gain from blended classes. A teacher who teaches many classes per day may not have enough time to prepare in the best possible way, or may not even be able to teach a large number of students, since the physical space is limited. By creating online classes (non-perishable), he/she will have more time to devote to other activities or to study and prepare new materials.

Cost reduction

Reducing costs is an advantage for both the institution and the students. Since it is not necessary to have a physical space every day to give classes, the courses can have a lower value, in addition to using free online tools to produce material and transmit the meetings.

Commitment to blended classes

Blended education is an excellent option to go beyond traditional education. Allying technology to education is a way to spread knowledge even further, in addition to incorporating institutions to the new reality of students, who are constantly in contact with the Internet. But do not think that this alternative is only for those who already work with education. Blended education can be an interesting method for in-company training, for example. Online courses are increasingly in demand and address topics from various areas.

The following are some experiences with the blended system used in the educational system of several countries:

When comparing academic performance in Microbiology and Parasitology, in medical students, with a quasi-experimental study in 58 students in the third semester of the career, using two educational modalities, one classroom and

one blended (classroom/online), it was observed that the overall result of the post-evaluation showed a difference in academic performance in favor of the experimental group (p = 0.016), demonstrating that the use of a blended modality as an educational strategy favors greater learning in medical students (Rosales*, et al*. 2008).

The in-person education model has been at the center of educational debates generating tensions due to the scarce incorporation of communication and information technologies, especially organizational technologies, both in the way of structuring classroom or institutional functioning, as well as in the organization of the educational system and the governance of institutions and the way in which teaching is organized (Rama, 2020).

In a study to explore the factors affecting the implementation of distance education in the pandemic context, globally, the main findings showed empirical and theoretical data such as difficulty in: Internet connectivity, access to equipment and technological and digital infrastructure and student-teacher relationships; weak digital competencies were also found; The conclusion was that the trend has been the increase in the use of information and communication technology to support educational activities, but at the same time access to these media is limited, leading to complex educational processes under the distance mode, which require expanding the search for strategies that minimize the difficulties imposed by reality, the alternative being the blended mode (Carbonell, et al. 2021).

It must be accepted that telematics technologies do not constitute an unquestionably effective resource for student learning, but must be integrated into a well-founded educational program in order to be applied pedagogically. Since the conjunction of all the elements related to the educational process (objectives, contents, methodologies, strategies, activities, etc.) are the indispensable conditions that allow telematics to really acquire an educational meaning, it is understood that at the heart of the educational process that takes place in the classroom is the interaction between individuals: teacher and student (Pastor, 2005).

It is perceived that the training processes in the online or virtual modality have not been sufficient to respond to the challenges of higher education in the digital era, and blended or blended learning is constituted as an alternative for digital teacher education in higher education, being an effective modality for digital teacher education courses because the in-person component complements virtual learning; in addition, given the problems of connectivity and internet access the blended learning modality is an alternative for continuous teacher training (Balladares, 2018).

The situation experienced by the pandemic and its consequences have led to the birth of a new *blended* teaching *model* that is in the process of conceptualization and experimentation. The scenario that is opening up only consolidates the trends of the importance of learning that enhances digital competencies in both teachers and students, as recognized by the European authorities (European Council, 2018).

The blended model of education requires transformations at two levels: pedagogical and organizational (De Obesso & Nuñez, 2021), in the pedagogical part, should take into account what is proposed by (Al-Samarraie, Teng, Alzahrani, & Alalwan, 2018; Huertas *et al*., 2018; Means *et al.,* 2014; Morán, 2012) in *e-learning* education and the current philosophy arising from Bologna, student-centered learning, applied to the design of blended educational programs in their three levels of interaction (Bernard *et al.,* 2009). At the organizational level, the institutional adaptations produced to integrate into business studies the transformations of the environment and students (Krishnamurthy, 2020) should be observed, taking into account the need for training in the skills of the future for the digital society of teachers, students and the university digital transformation itself (Holford, 2019; Ladevéze N. & Núñez, 2016; OECD, 2018).

The pedagogical model of blended learning is increasingly used in higher education, due to the fact that it promotes significant changes in learning, this conception implies the opening to effective opportunities for dialogue and collaborative construction of content, as well as the promotion of digital culture in terms of collaborative and cooperative activities between managers and teachers to act differently in the classroom (Mejía*, et al*. 2017).

According to Badrus & Arifin (2021), the advantages of blended education are as follows:

1. Virtual interaction among students allows for direct participation in questions and answers that complement the learning context.
2. Links to videos or documents, virtual repositories of practices and texts, help to reinforce what has been learned in class, where the environment can be personalized with basic questions that allow a better interaction and experience with the student.
3. It allows for the creation of more meaningful personalized learning environments, enabling improvements in young people's performance and outcomes.
4. More flexible schedules, and savings on transportation costs and work and study materials, as well as having the best teachers regardless of location.

5. It focuses on learning, since the time for practices, exams and evaluations can be deferred to online processes, allowing for more discussions and exchange of ideas in the classroom.
6. Instant feedback once an evaluation has been submitted saves the teacher productive time, where you can even customize the messages you want to send to students according to the grade obtained.
7. Of course, the savings on consumables such as paper, pens and so on. This advantage is more related to the environment and its care, but it is also part of the benefits of blended education.

The disadvantages are the following:

1. Lack of discipline in time management and organization can generate vulnerability in the educational process.
2. Poorly participatory students tend to have lower comprehension and grade at the end of each process.
3. The availability of computers, laptops, smartphones, internet, signal, among others, can generate difficulties due to the impossibility of use or schedules of activities in people who share this technology.
4. It is also possible that some students may not feel motivated in this modality because of the lack of direct interaction in a classroom with their peers.
5. Student distraction is more difficult to correct or control due to the impossibility of transmitting bodily or gestural messages by the teacher.
6. Teachers must be continuously updated on the innovations and tools that appear in order to be competitive in the educational environment.

MATERIALS AND METHODS

The sample consisted of four hundred students who studied the fifth level of the aforementioned career, divided into 8 different academic semesters, during 4 consecutive years (2018, 2019, 2020 and 2021), two in classroom system and two in blended system (classroom and online) of an institution of higher education (IES) of Ecuador, having exercised the teaching of the subject the same teacher with a Master's degree in Biotechnology and PhD in Veterinary Sciences, being the research executed quasi-experimental type.

For the purposes of this research, the in-person strategy was operationally defined as the modality in which students attend the classroom to have classes in the presence of the professor and following his work instructions, and the blended modality (in-person/online) as the situation in which students attend the classroom to have collaborative work sessions and discussion guided by the instructor based on the online course, as well as the laboratory to perform the experimental practices. This implies that students must read the contents of the virtual classroom created for this purpose and carry out the activities and learning experiences programmed in the course *website*.

On the other hand, the dependent variable was academic achievement, defined as the result of the measurement of the knowledge acquired in the subject of Food Biotechnology, through the previously validated instrument, expressing its result in a numerical value ranging from 0 to 100 (Percentage).

To measure the results of academic performance in the study groups, an instrument composed of 100 *items* was previously constructed and validated*, with* a predominance of multiple-choice answers, considering the following five areas of knowledge that make up Food Biotechnology:

1. Biotechnology, history, current status and prospects
2. Principles of Genetic Engineering applied to Biotechnology
3. Production of food and other biotechnological products
4. Quality control in biotechnological products
5. Bioethics and its applications in biotechnology

The validation process of the instrument used was carried out by three professors from related areas of the same career. Three rounds were carried out with the reviewers until an agreement was reached, emphasizing the clarity of the questions, coherence with the contents to be evaluated and relevance, as well as updating in terms of knowledge advances. In addition, the internal consistency of the previously validated evaluation instrument was calculated.

The alternate hypothesis tested was that students using the blended modality acquire higher academic performance compared to students attending a in-person course.

A pre-evaluation (diagnostic test) was applied to each group at the beginning of the academic period, using a questionnaire with multiple choice questions as follows:

Two of the sciences that integrate Biotechnology are:

a) Biology and Enology
b) Biochemistry and Macrobiology
c) Microbiology and Genetics
d) Medicine and Cloning

Correct answer: C **Value in points**: 1

In a broad sense BIOTECHNOLOGY is the use of:

a) Interesting chemical molecules, cells or organisms for specific processes
b) Biologically obtained molecules, cells or organisms for specific processes
c) Molecules obtained in reactors, cells or organisms for specific processes
d) Genetically modified molecules, cells or organisms for specific processes

Correct answer: B **Value in points**: 1

The post-evaluation was carried out eight days after the end of the course. The courses had a duration of 16 weeks each. The first 4 groups or parallel groups received the classes in the traditional way, using the in-person modality with the teacher in charge of the course. On the other hand, the development of the blended modality, applied to the other 4 groups, consisted in the development of the indicated course in online sessions, for which a virtual classroom was built, nested in an institutional *Web site* under a Moodle platform (Figure 1), in which the student was provided with theoretical information, with links and file consultation, in which the activities necessary to acquire the learning were specified and the practices were in-person in a physical laboratory with adequate infrastructure.

Figure 1. Screenshot of the virtual classroom format of the Food Biotechnology course (Spanish)

Source: retrieved from the application of virtual classrom

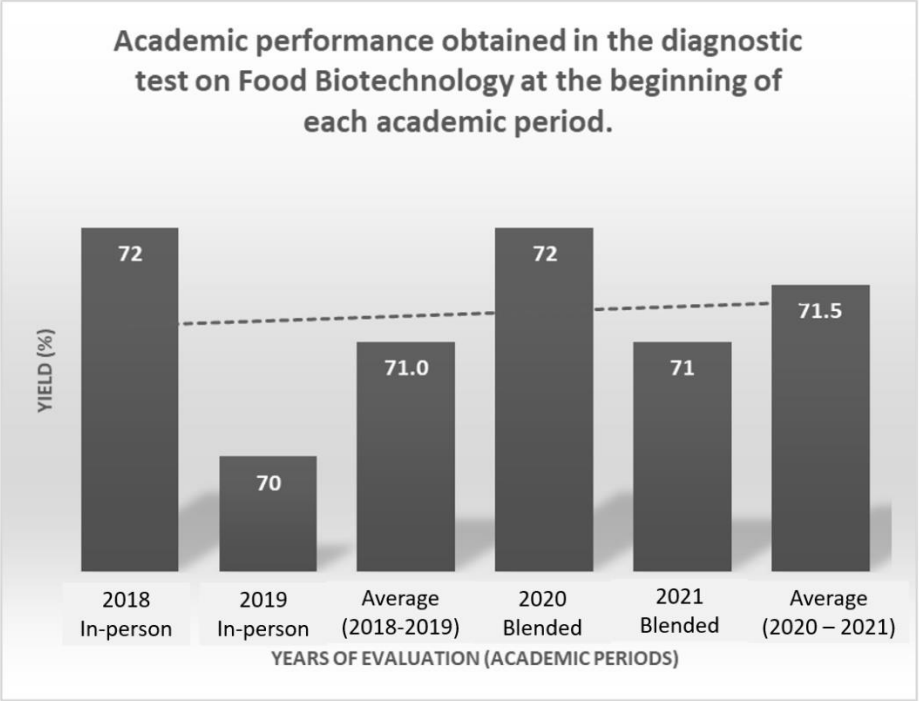
The online readings shown through the links were previously selected by the teacher according to the thematic content of the subject, which allowed the student to access the information in different formats (pdf, power point) and from other Web sites. In order for the student to be informed of the activities scheduled for the in-person and online sessions, messages were sent through the work group created on the WhatsApp platform.

Students with less than 70% attendance during the research period were eliminated from the study. The data obtained were analyzed using descriptive statistics and a Student's t-test ($P \leq 0.05$).

RESULTS AND DISCUSSION

During the study, a diagnostic test was performed at the beginning of each academic period within the 4 years of study, which consisted of applying to all students in this work, a standardized test of 100 questions on knowledge considered as basic, necessary or prior to Food Biotechnology, having obtained as a general result that there are no statistical differences between the years of evaluation, Thus, for 2018 the academic performance of the students submitted to the diagnostic test was 72%, for 2019 it was 70%, these two years under the in-person modality, likewise for the blended modality, i.e. for 2020 the performance was 72% and for 2021 it was 71%, which shows that the students started from a similar knowledge base, so it is expected that there was no influence of this basic knowledge on the subsequent results (Figure 2).

Figure 2. Academic performance of students in Food Biotechnology evaluated by means of the diagnostic test at the beginning of each academic period of the 4 years of study under the two educational modalities (classroom and blended)



Source: own elaboration with the research data (2023)

As can be seen in Table 1, it was found that there is a higher level of learning of the knowledge of Food Biotechnology when the education system uses the blended modality, in such a way that statistical differences ($P \leq 0.05$) are evident between the two modalities studied, thus, with the in-person education system a 78 ± 3.04 % of learning of the knowledge of this science is achieved, while with the blended system 86 ± 3.02 % was obtained.

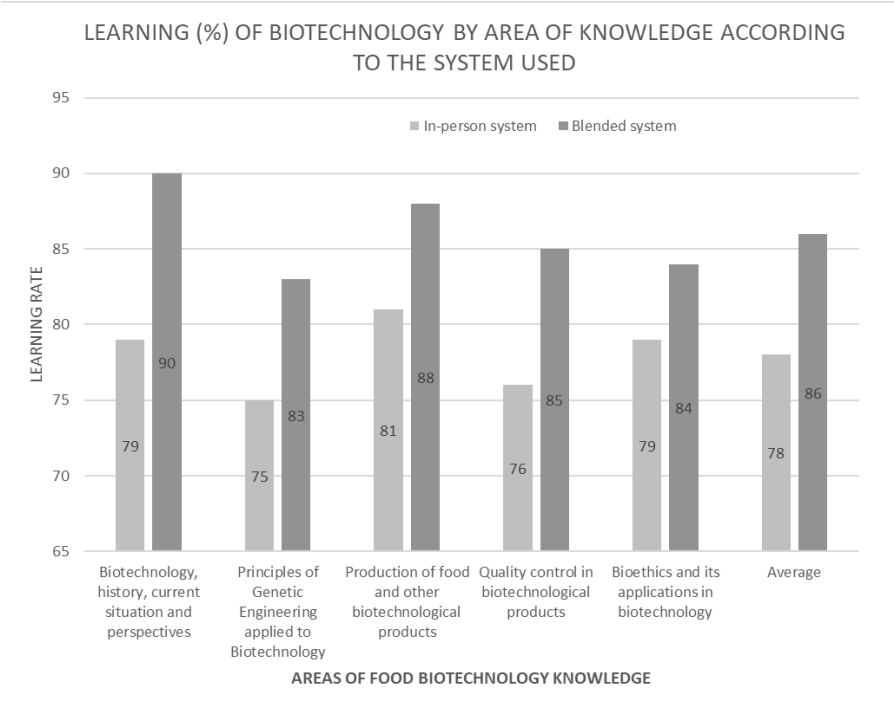
Table 1. Level of learning (%) of the areas of knowledge of food biotechnology according to the system of education used

AREA OF KNOWLEDGE	% LEARNING				
	In-person system	SD	Blended system	SD	p*
Biotechnology, history, current status and prospects	79	±2.1	90	±4.1	0.045
Principles of Genetic Engineering applied to Biotechnology	75	±1.3	83	±2.3	0.038
Production of food and other biotechnological products	81	±5.2	88	±3.2	0.023
Quality control in biotechnological products	76	±1.2	85	±4.2	0.017
Bioethics and its applications in biotechnology	79	±5.4	84	±1.3	0.028
AVERAGE	78		86		

Source: own elaboration with the research data (2023)

Figure 3 shows the behavior of the results obtained by evaluating the level of learning achieved within each of the components of Biotechnology considered for this study, both for the classroom system and for the blended modality, where it can be seen that for the first component: Biotechnology, history, current situation and perspectives, students acquire and settle knowledge in 79±2.1 % while for the blended system they do so in 90±4.1 %, this shows that the latter makes possible a better learning of this biological science. For the second component: Principles of Genetic Engineering applied to Biotechnology, a similar result is obtained, i.e. learning improves from 75±1.3 % with the classroom system to 83±2.3 % with the blended system, this trend is repeated for the remaining three components of biotechnology: Production of food and other biotechnological products, quality control in biotechnological products, bioethics and its applications in biotechnology, with values of 81±5.2; 76±1.2 and 79±5.4 % learning respectively achieved with the in-person educational system, while with the blended system they improve to 88±3.2; 85±4.2 and 84±1.3 % in their order for the same components, finding significant differences when comparing between the two educational systems under study.

Figure 3. Level of learning (%) by areas of knowledge of food biotechnology according to the education system used



Source: own elaboration with the research data (2023)

As can be seen in Table 2 of results, the evaluation carried out for four consecutive years on the level of learning of the knowledge of Food Biotechnology in students of the Agro-industrial Engineering career of an Ecuadorian public University, shows that in the first year of study (2018) a learning percentage of 75±3.0% is obtained, increasing slightly for the following year (2019) to a level of 81±2.6% under the same modality, with an average value for the two years of its application of 78%, this is the in-person system, while when applying the blended teaching modality for Biotechnology a learning level in students of 86±2.8% was obtained in the first year of its application (2020) and the same value, that is 86±2.9% in the second year of its validity (2021), evidencing an increase in learning around 8% with statistical differences between the two systems.

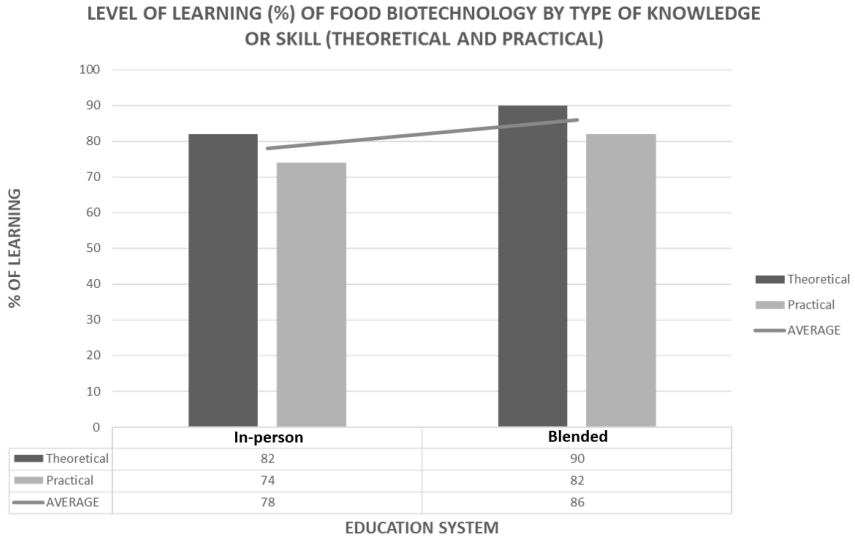
Table 2. level of learning (%) by component of knowledge of food biotechnology by year

COMPONENT	EDUCATIONAL SYSTEMS BY YEAR									
	IN-PERSON SYSTEM					BLENDED SYSTEM				
	2018	DS	2019	DS	PROM.	2020	DS	2021	DS	PROM.
Biotechnology, history, current status and prospects	77	±3,6	81	±2,7	79	86	±1,6	94	±3,1	90
Principles of Genetic Engineering applied to Biotechnology	74	±2,8	76	±3,6	75	85	±2,2	81	±2,3	83
Production of food and other biotechnological products	76	±4,2	86	±2,6	81	91	±3,9	85	±3,3	88
Quality control in biotechnological products	75	±2,9	77	±1,9	76	81	±4,1	89	±2,5	85
Bioethics and its applications in biotechnology	74	±1,5	84	±2,3	79	85	±2,4	83	±3,4	84
AVERAGE	75		81		78	86		86		86

Source: own elaboration with the research data (2023)

When analyzing the results obtained for the learning level of Food Biotechnology by type of knowledge or skill, that is, theoretical or practical, as shown in Figure 4, it was obtained in the study that with the classroom system 82% of learning is achieved for the theoretical part and 74% for the practical part, that is, skills with laboratory work, while with the blended system these learning levels are increased to 90% for the theoretical part and 82% for the practical skills. Let us remember that these values were obtained through the application of a test-type instrument of 100 indicators applied during 8 consecutive academic periods in the Ecuadorian higher education institution to students of the subject under study.

Figure 4. Level of learning (%) for food biotechnology according to type of knowledge or skill (theoretical and practical)



Source: own elaboration with the research data (2023)

The study in question considered the evaluation of two systems for a subject of importance and wide applicability, the first pre-pandemic one known as in-person, which despite its great trajectory and use over time, shows limitations in the field of higher education, on the one hand, is a determinant component of educational inequality, since it imposes a centralized, unique and costly spatial location, a power structure focused on large cities that has marked inequalities in regional access, resulting in concentration and exclusion. On the other hand, this educational methodology is predominantly based on a learning paradigm based on rote repetition in the classroom, rather than on the study of learning resources; even the study of books is concentrated in large libraries as the center of universities (Rama, 2020).

The second method evaluated was the well-known and recently applied given the circumstances of the country and the world due to the pandemic, the blended system, which is understood as a totally virtual modality but which differentiates between synchronous and asynchronous forms of learning, with a diversity of degrees of use according to the learning objectives and contents. It is not a blended education that combines a in-person teaching with a support on platforms, high diversity of interaction systems and educational work of teaching in virtual environments, mostly are supported on the network and on computers, cell phones or tablets, it is a dynamic that is structured both in the form of continuous education, as discontinuous, relying on multimodalities, finally it is supported by a tertiarization in the technological aspects of both connectivity (associated with synchronous forms: Zoom, Google, Team) as well as platforms with tutors, both LMS models such as Moodle, Canvas, Schoology, Blackboard, etc.), as well as platforms that support MOOCs and applications in computer labs of simulators or augmented reality to acquire skills (Rama, 2021). As expected, blended education also has limitations, since digital disruption has created multiple social gaps and the pandemic has starkly revealed these weaknesses in digital development and the differentiated level of access and use among the various sectors and regions. This weakness in the digital development of the Latin American region manifests itself as limitations for the realization of telework and distance education, but also in many other areas: telehealth services, tele-justice, digital commerce, digital government, digital banking, etc. In almost all cases, this derives from legal constraints, productive structures, types of infrastructure, level of training and technical skills of the various actors, limited innovative management models that give them administrative support or ideological and cultural resistance (Rama, 2020).

Thus, blended learning or blended learning is an integrative learning modality that uses in-person and virtual components in a combined manner. A review of different bibliographic sources revealed experiences and research results on the use of blended learning for the online professional development of university professors. Among the results, it is perceived that the training processes in the online or virtual modality have not been sufficient to respond to the challenges of higher education in the digital era, and blended or blended learning is constituted as an alternative of digital education of teachers in higher education (Balladares, 2018).

The main findings in the study "From distance education in pandemic to blended modality in post-pandemic" showed empirical and theoretical data referring to: difficulty in internet connectivity, access to equipment and technological and digital infrastructure and student-teacher relationships; weak digital competencies were also found; Thus, the trend has been the increase in the use of information and communication technology to support educational activities, but at the same time access to these media is limited, leading to complex educational processes under the distance mode, which require expanding the search for strategies that minimize the difficulties imposed by reality, the alternative being the blended mode (Carbonell, *et al*. 2021). When comparing the academic performance in Microbiology and Parasitology, in medical students, through a quasi-experimental study in 58 students of the third semester of the career, using the two educational modalities, classroom and blended (classroom/online), the overall result of the post-evaluation showed a difference in academic performance in favor of the group under the blended modality, so it would seem that the use of this modality as an educational strategy favors greater learning in medical students (Rosales, *et al*. 2008). This behavior was corroborated in our study, where the blended system delivered better learning results in Biotechnology than the in-person system. Thus, the traditional educational methodology should be developed towards an innovative approach, which contemplates the changes that arise in teaching when using different methodological resources. In addition, information and communication technologies, due to their interactivity, stimulate cognitive, emotional and sensitive capacities (Fuentes, Cruz and Pastor, 2005).

As teachers, we have proven that the use of the Internet offers important advantages to the traditional didactic method, especially with regard to the wide and updated availability of educational material (Calatayud, Martínez, Muñoz and Cuenca, 2005), an advantage that is optimized with the teacher's commitment in the learning process. It is recommended that learning be mediated by activities designed to improve students' understanding and the meaning of knowledge, through interaction with the same material at different times, in contexts reconfigured for different purposes and interaction among peers to share knowledge, generating reflection and active engagement of students (Cenich and Santos, 2005).

Some studies have shown that students learn better on the *Web* than in traditional classes (Araya, 2007; Avila and Samar, 2004; Gallego and Martinez, 2003; Popescu and Navarro, 2005), based on the above, the teacher must motivate the student to build knowledge, using the new technological alternatives. In this mixed modality (in-person/online) students attend the classroom to have discussion sessions guided by the teacher, based on the course content on the web. This implies that students must read the contents of the *Web site* pages as well as carry out the activities and learning experiences programmed therein (Longoria, 2005).

The results of this work and those of the other authors show that the blended modality alternative to in-person mode is gaining ground, from a formal point of view, as it becomes evident that a return to the previous stage seems unfeasible, since the changes generated seem to be here to stay, although it is an evolving process (Carbonell, *et al*. 2021). Thus, higher education institutions must rethink the model to be used and redesign their educational structures. Wold (2013) maintains something similar, stating that blended education is projected into the future as a modality that contributes to the improvement of the quality of higher education, in the same way Owston, *et al*. (2008), indicate that this model will be a good contribution to the professional development of teachers. Concomitant to these criteria, Balladares (2018), states that in a literature review from 1999 to 2012 on research about Blended Learning, researchers Güzer and Caner (2014), perceive this modality as useful, pleasant, flexible and motivating for learners, although it has as a challenge to generate better learning environments through social interaction and collaborative work. It seems that these characteristics helped in our Biotechnology course to obtain better results in the learning of the evaluated students.

Other researchers such as Valverde, *et al*. (2004) indicate that blended learning becomes an alternative modality for the improvement of teaching-learning processes and constitutes a trend in the use of ICT for university teaching. Likewise, Fainholc (2008) indicates that this modality is considered ideal for the professional development of teacher training students. In this way, blended learning is an option of virtual educational modality integrating traditional and innovative, in-person and virtual, formal and non-formal, synchronous and asynchronous components, different languages, teaching approaches and learning styles (Valverde and Balladares, 2017). We already see today in a variety of institutions, regions and countries that the knowledge society and higher education systems tend to combine a blended model that incorporates in-person and distance modalities, so that in the future it will not make sense to distinguish between these two types of education (Pastor, 2005).

It is therefore no coincidence that Morán (2012), argues that blended learning, flexible education, widely known by its English term *blended learning*, or blended education, as a mixed category between online and traditional education, arises in the business environment, offers an integration in the same learning process of educational elements carried out through technological means with education offered in the more traditional way (Thorne, 2003). This combination can occur in many ways: online subjects and in-person subjects, part of online subjects or only certain formative activities, therefore educators agree that this approach shares the opportunity to provide personalized instruction with some element of student control over the teaching-learning process, time and place (O'Byrne & Pytash, 2015), cited by De Obesso, M. and Nuñez, M. (2021).

It is important to quote Obesso, M. and Nuñez, M. (2021), who in their work "The blended educational model: a necessary response of university education from Covid-19", conclude and propose to analyze this model from the results obtained from the educational experiences emerged in the years 20-21, observing the main transformations at two levels: pedagogical and organizational. On the pedagogical side, from the dimensions of analysis developed by the general literature of *e-learning* education (Huertas *et al.,* 2018) and the current philosophy emerged from Bologna, student-centered learning, applied to the design of blended educational programs in their three levels of interaction (Bernard *et al*., 2009). At the organizational level, observe the institutional adaptations produced to integrate into business studies the transformations of the environment and students (Krishnamurthy, 2020), taking into account the need for training in the skills of the future for the digital society of teachers, students and the university digital transformation itself (Holford, 2019).

The existing scientific literature continues to argue that the blended learning pedagogical model is increasingly used in higher education, due to the fact that it promotes significant changes in learning, this conception implies the opening to effective opportunities for dialogue and collaborative construction of content, as well as the promotion of digital culture in terms of collaborative and cooperative activities between managers and teachers to act differently in the classroom (Mejía, *et al*. 2017). It can be stated then that the education of the future must enrich the potential of students and have them as protagonists in the teaching-learning process, where the teacher must guide them towards a comprehensive training, which includes the development of cognitive and socioemotional skills and the use of new technologies as a research tool for learning, communication and dissemination, so that learning is developmental (López, *et al*. 2012).

At this point of the analysis it is convenient to cite an experience similar to ours, which when evaluating the students of a graduate program taught under both in-person and blended modalities, through questionnaires and discussion groups, found that the blended model adopted (in-person/online) was adequate, the students' discourse shows that they were committed to the benefits of the modality, however the typical didactic and pedagogical problems common to the teaching-learning process, such as distance tutoring, were maintained (Lavigne, 2006). However, it is necessary to consider the proposal of contemporary scientists, who have identified different sets of variables that should still be evaluated in the blended educational system: those of the socio-economic context, those of the learning environment, those of technology, those of pedagogy and those of the students (Hughes and Attwell, 2003).

Similarly, in the area of blended pedagogical training practices for teachers in education, there is a tendency to transform the training processes by the combination of various pedagogical trends such as cognitivism, constructivism and behaviorism with e-learning (Torres and Gutierrez, 2017).

Continuing with the analysis and discussion of this interesting educational topic, it was found that indirect empirical indicators and conceptual frameworks allow us to assume a persistent growth of non-attendance enrollment in Latin America. This process has a broad set of drivers as a derivation of economic, political, social, academic and technological logics, which have begun to outline a new element within the process of differentiation of higher education in Latin America within the framework of enrollment expansion, and which feed back, reinforcing this new component of a blended education in the region and of the trend towards a respectable segment of the coverage of Latin American higher education, marked by its de-presentialized character (Rama, 2007).

In Ecuador, the higher education regulatory body, the Higher Education Council (CES), (2020) in view of the Covid 19 pandemic in Ecuador, incorporated in its transitional regulations an article to guarantee the continuity of students' studies, HEIs may adapt their career plans and programs to the blended modality, combining blended, online and distance learning modalities. This teaching modality will prioritize the autonomous learning of students, which requires that all courses, subjects or their equivalent contain a study guide developed by the academic staff. In order to strengthen students' autonomous learning processes, as well as the broadening, deepening and specialization of knowledge, HEIs must offer students open access to at least one virtual library and a digital support repository. In such a way that the challenges of the blended model is that the digital competence of teachers must be continuously updated, focusing their skills in the mastery of digital tools and methodologies for appropriate assessment (Guamán, *et al*. 2020).

As a valid experience that corroborates the work under discussion, it is appropriate to cite Sousa, *et al.* (2021), who when evaluating the effectiveness of blended teaching with *flipped classroom*, in terms of student satisfaction and *performance*, compared to 100% *online* teaching in different IES (Higher Education Institutions), identified statistically significant differences in relation to academic performance where students are very satisfied with the blended environment and the *flipped classroom* methodology, with better success rates and better retention compared to fully *online* teaching. In recent research that is online, the results obtained are encouraging and could suggest that the application of *flipped classroom* in blended subjects generates an educational environment that improves student performance (Hinojo, *et al*. 2019). Apparently and as several positive experiences of results with blended education have been cited in this work, it would seem to be an excellent option, since it is an ideal educational model to prepare students in a world where knowledge is not a fixed set of facts that can be easily divided into independent subjects (Viñas, 2021).

Contemporary researchers recognize that remote education responded to the emergence of the pandemic and identified key success factors such as the temporalization of the teaching and learning process, synchronous teaching, the techno-pedagogical design of virtual learning environments, and the digital transformation of universities. These results make it possible to redefine the traditional concept of blended education, incorporating the strengths of remote education and repositioning it as a strategic study modality for a new educational normality that progressively recovers in-person teaching and expands student learning (Balladares, 2021).

However, one cannot leave aside the results of some research that seem to contradict in practice the advantages of blended education, since this type of university training originates a lack of professional identity among blended professionals and a notable absence of social recognition of the profession by employers as a whole, both situations could well affect the rapid insertion of graduates with blended training into the labor market (Damian, 2014).

Finally, it should not be forgotten that an important link in the process of transformation towards quality education is the participation of the government, which, seeking the welfare of the population, establishes projects for Internet accessibility, technological equipment in classrooms and the provision of computer equipment to students (Ríos, 2021).

Limitations of the study

Possible theoretical limitations include the study's limited generalizability beyond the specific context of agro-industrial engineering studies in Ecuador, potentially restricting broader theoretical implications. Additionally, the absence of a comprehensive theoretical framework may constrain the depth of understanding regarding the underlying mechanisms influencing learning outcomes in biotechnological education.

Methodological limitations arise from the study's reliance on a single university and a relatively small sample size of 400 students, potentially limiting the generalizability of findings. Furthermore, the non-random assignment of students to educational modalities (presential vs. hybrid) may introduce selection bias, affecting the comparability of groups and confounding results. These limitations underscore the need for caution in interpreting and applying the study's findings to broader educational contexts.

CONCLUSIONS AND FINAL REMARKS

Food biotechnology as a professionalizing subject in the engineering career is apparently and according to the results of this work, better understood and applied through a blended system of education, so it is recommended to take into consideration these data to implement blended education systems for this science and other related biological sciences in university careers in Ecuador.

Based on the results cited from various research works in the educational field, as well as based on our own experience of university educational work, we could cite as advantages of the blended system the cultivation of autonomy, learning is enhanced, greater flexibility of time and schedules, better use of time, reduced costs, greater interaction due to the diversity of available resources, better use and exploitation of content, design of personalized environments, the possibility of instantaneous feedback, among others. The system also has disadvantages such as the vulnerability of the educational system, the segregation of students who do not participate much, the non-existent and inequitable existence of electronic equipment for connection, the lack of motivation, the need for permanent teacher training, greater student distraction, among others.

Given the current pandemic circumstances that continue to influence educational systems, it is necessary to redesign the structures of the curriculum, the tools to implement educational processes and adjust to the undeniable reality of a transformation, which is why the use of the blended modality of education in higher education should be considered in the processes of curriculum redesign.

A potential agenda for future studies in the field of biotechnological education could encompass a multifaceted approach, including investigations into the effectiveness of diverse pedagogical strategies, such as flipped classrooms or project-based learning, in enhancing learning outcomes. Additionally, longitudinal studies exploring the long-term impact of different educational modalities on students' retention of biotechnological knowledge and their ability to apply it in practical settings would provide valuable insights. Comparative research across various educational institutions and cultural contexts could further elucidate the factors influencing learning outcomes in biotechnological education. Moreover, investigations into the integration of emerging technologies, such as virtual reality or simulation-based learning, into biotechnological curricula could offer innovative approaches to enhance student engagement and comprehension. Finally, qualitative inquiries exploring students' perceptions and experiences of different educational modalities would complement quantitative analyses, providing a comprehensive understanding of the complexities involved in biotechnological education.

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