Experience of Information Students from an Ecuadorian University for the Application of ICT in Project-Based Mathematics Learning (ABP)

CRISTIAN INCA[1], ANDRÉS MOROCHO[1], FRANKLIN CORONEL[1], ANGEL MENA[1],
EVELYN INCA[2,a], JOSEPH GUERRA[2,b]
[1]Facultad Departamento de Informática y Electrónica,
Escuela Superior Politécnica de Chimborazo (ESPOCH),
Km 1 1/2 Panamericana Sur, Riobamba, EC060155,
ECUADOR

[2]Independent Researcher
Riobamba, EC060108,
ECUADOR

[a]ORCiD: https://orcid.org/0000-0001-7055-9019
[b]ORCiD: https://orcid.org/0000-0003-4669-7715

Abstract: - Mathematical knowledge is a basic tool for understanding these processes, however, its learning can be abstract, causing some difficulties for students to understand it, which is why pedagogical alternatives (ABP) have been developed, which allow the resolution of real problems through the execution of projects in the mathematical field, in this case supported by information and communications technologies. The usefulness of this tool in learning was evaluated through its application in a group of 20 students from the information technology major at the Polytechnic School of Chimborazo (ESPOCH), 10 before the use of the APB and 10 after its use, comparing the changes in the academic performance of students after the application of the ABP, as well as the perception of students in relation to the interest, value, motivation, and usefulness of mathematics through the management of information from Ecuadorian databases for the construction of equations that allow, through the use of derivation rules, to analyze the behavior of elements of economic interest. The results obtained were satisfactory when observing an increase in grades after the implementation of project-based learning since, it was observed that 57.6% of the students adequately understood the dictated contents and 65.76% correctly used ICT for teaching. Obtaining statistical information for the construction of mathematical equations, which is done correctly in 62.69% of the cases, is a product of greatest interest (56.70%) and motivation (54.20%) to do it, which was expressed in a higher level of competencies (58.30%) in the area of mathematics, even with a lower level of tension (31.35%) and greater commitment (64.10%). The results of the achievements achieved by the students allow us to conclude that the use of ABP is effective in learning mathematics, especially if the skills of the area of knowledge are combined with the appropriate use of information and communication technologies.

Key-Words: - Project-Based Learning, university education, meaningful learning, mathematical knowledge, equations, estimates, derivatives, ICT, academic performance.

Received: January 26, 2024. Revised: July 9, 2024. Accepted: August 7, 2024. Published: September 4, 2024.

1 Introduction

With the advance of the Internet, the educational system has turned towards massive use of information and communication technologies (ICT), which includes the use of virtual learning environments [1], the management of social networks such as Facebook, Twitter, and Instagram, combined with the use of audiovisual applications that allow greater student interaction. This has made it possible to facilitate remote learning [2], either synchronously or asynchronously [3], allowing the inclusion of groups previously excluded from the formal educational system, [4].

The rise of this technology has been such that professional careers have been created for its use, which is attractive for the use of computer tools due to the familiarity presented by the groups known as millennials, [5]. However, there is a lack of

knowledge of the skills that must be acquired throughout this career, which are not limited to the use of digital tools [6], but must also include mathematical skills for their design, [7]. These tools are based on complex algorithms for mathematical calculations, which requires the curricular plan to include the study of mathematics.

Considering the above, this constitutes a barrier since the study of mathematics is complex and highly difficult for students, [8]. Indeed, the reality lies in the fact that students do not understand their usefulness and, in association with the construction of digital tools that are part of the catalog of products within information and communications technologies, the usefulness that can be given to them, [9]. As well as the correct use of databases in solving real problems that occur in the real world, [10], [11] and [12].

Given the problems described in the previous paragraphs, learning strategies have been sought to motivate interest and greater understanding in the study of mathematics. Project-based learning (ABP) is one of the selected strategies since its use achieves the development of mathematical skills based on the resolution of real problems, [13]. In the Ecuadorian case, due to the efficient management of databases [14], can facilitate the work of students in their use for the construction of differential equations [15] and the use of derivation [16]. Consolidating the integration of the above with the management of ICT in mathematical applications, should motivate and promote greater interest in their study by understanding their value and usefulness in the real field, [17].

The adoption of new learning strategies results in one of the difficulties observed within mathematics classes, represented by the mechanical and repetitive way in which the learning activity occurs. In this sense, authors such as [18] affirm that this problem is due to the strategies used by many teachers since learning methods are based on the memorization of concepts or the repetitive performance of procedures on a routine basis, without carrying out an in-depth analysis to understand how it was possible to reach the solution through logical and deductive analysis. This type of learning makes it difficult to extrapolate knowledge to real applications and causes a decrease in student's motivation to learn, as suggested by [19], who state that the teaching process should focus on improving the ability analysis to propose solutions to problems that affect the normal functioning of day-to-day activities in society.

Researchers in [20] point out that learning from the formulation of real problems has been identified as a relevant aspect of teaching mathematics education and has begun to be used more regularly in the training process, [21]. In this sense, an increasing number of didactic proposals are presented that try to work on the reasoning through problem-solving, which translates into a successful methodology by increasing student's motivation to learn and improving the efficiency of the problem-solving in terms of quality and time.

The pedagogical strategy for project-based mathematics learning has become a valid option for learning statistics. This statement coincides with what was stated in [22] by stipulating a methodology that allows the integration of the student's goals with the previously established curricular design and the needs of society, mainly within the scope of action of the educational institution.

Considering the above, this research focuses on an exhaustive methodological development that allows data analysis, obtaining findings, and achieving results with discussions consistent with the underlying reality under study. In this order, the objective is defined by project-based methodological evaluation (ABP) as an optimizer of the teaching-learning process of mathematics. This is in order to build a project that encourages cooperative work. The underlying intention is for students to integrate the acquisition of knowledge and the development of their skills through motivation and an active role in undertaking data analysis obtained through the optimal management of information and communications technologies (ICT) for the construction of differential equations and the resolution of problems based on real data.

2 Materials and Methods

2.1 Contextualization

The research work was carried out at the Faculty of Sciences of the Higher Polytechnic School of Chimborazo in the Information and Communications Technologies (ICT) program. This delimitation arises in accordance with the interest of the research since in this department mathematical calculation is taught with emphasis on the skills for the use and management of databases obtained through the proper management of ICT for the construction of mathematical equations and the subsequent application of derivation rules. This institution is a higher education establishment located in Riobamba, Ecuador (Figure 1), and has been part of the Ecuadorian Network of Research and Postgraduate Universities since 2012.

Fig. 1: Location of the Chimborazo Higher Polytechnic School

This educational institution was created on April 18, 1969. It began its academic activities on May 2, 1972, with the Schools of Zootechnical Engineering, Nutrition and Dietetics, and Mechanical Engineering. It was inaugurated on April 3, 1977. Accredited by the National Council for Evaluation and Accreditation of Higher Education of Ecuador (CONEA) in 2022. Currently, this organization no longer classifies Ecuadorian universities by categories, managing to define itself as excellence. Within higher education, with equipment, furniture, educational services, qualified teaching staff, educational demand, and pedagogy, among many other points that characterize its study profile.

Being an Ecuadorian Higher Education Institution that originated in the Higher Technological Institute of Chimborazo created by Law No. 69.09, issued by the National Congress on April 18, 1969. It began its academic activities on May 2, 1972. Chimborazo Higher Polytechnic School is currently made up of 7 faculties and 2 campuses that offer 44 professional careers.

2.2 ESPOCH Educational Model

The educational model based on "Know, Be, and Serve" competencies allows for the inclusive management and transformation of student's experiences in different learning environments, thus enabling the creation of academic itineraries of quality and excellence. That is, the various professions are subject to rapid change as the frontiers of knowledge exceed local and national boundaries, in which case students must be trained as citizens of the world.

Indeed, the definition of the educational model that underpins training at ESPOCH focuses on the development of competencies, aimed at consolidating the skills, knowledge, and attitudes that students need to be successful in their professional and personal lives. This model is implemented through different methodological strategies, such as learning based on problem-solving, collaborative learning, and autonomous learning.

The competency-based educational model is student-centered, based on a holistic approach to ethical management, and contextualized in the functions performed by academic staff, the student sector, and other agencies involved in academic activity. Aimed at promoting the construction and reconstruction of their own knowledge in a collaborative manner through transformative and innovative learning linked to technology, artificial intelligence, and sustainability.

2.3 Population and Sample

The population is made up of 26 students enrolled in the mathematical calculation course, of which 11 were enrolled in the course before the application of the ABP and 15 after the ABP, located in the academic computer programming program of the ESPOCH, from which a sample of 20 students was obtained (10 before the use of the ABP and 10 after its use). For the application of the IMI questionnaire in the academic periods evaluated, divide the study into two phases before and after the use of the ABP strategy.

2.4 Participants

The academic year in which the research is carried out is in the subject of mathematical calculation for the Information and Communications Technologies (ICT) career. It was made up of twenty (20) students who were assigned a mathematics project to solve real problems using mathematical tools based on the information obtained from data through the proper management of ICT for the construction of mathematical equations and the subsequent application of derivation rules. Determining performance and efficiency metrics that were compared with the conditions prior to the application of this learning strategy.

2.5 Variables

The variables evaluated for the comparison of project-based learning (ABP) versus the exclusive use of face-to-face education through master classes were carried out through the estimated evaluation of the degree of satisfaction with its use by mathematical calculation students. In this sense, the following parameters were considered: knowledge, understanding, enjoyment, effort, collaboration, and the usefulness of the learning process based on the use of multimodal educational systems.

2.6 Instruments

To evaluate the degree of student satisfaction once the project-based learning model was applied to the

mathematical calculation subject, information was collected by applying the IMI questionnaire, which is described below.

2.7 IMI Questionnaire

For data collection, the motivation questionnaire and the IMI satisfaction level were used by mathematical calculation students after the use of project-based learning systems. This is an instrument that has been previously validated by numerous studies on motivation, with measurements of the level of acceptance and motivation of students for learning statistics, [23].

For the evaluation, aspects related to knowledge, understanding, enjoyment, effort, collaboration, and usefulness were considered. These aspects were evaluated on a scale with 5 levels described below: a lot = 1, quite a bit = 2, somewhat = 3, a little = 4, and not at all = 5. This instrument was applied before the implementation of the learning strategy based on multimodal systems and after the delivery and evaluation of the project. Ratings 1 and 2, Mucho and Quite a Lot, will be categorized as positive evaluations.

The questionnaire used to establish the degree of knowledge and motivation prior to using the project-based learning (ABP) tool, applied to mathematical calculation students, is described in Table 1.

Table 1. Questionnaire on motivation prior to the use of project-based learning (ABP) by mathematics students in the Information and Communications Technologies (ICT) program

Questions	A lot	Quite	Something	A bit	Nothing
The activity can be academically interesting.					
The introductory material for the project has been understood.					
I feel nervous/tense about the activity to be carried out					
The activity represents a personal challenge.					
The idea of working in a group is attractive to me.					
The activity can strengthen my relationship with my classmates.					

This prior application instrument is sized into six items that reflect the expectations for competencies that students perceive prior to the implementation of project-based learning (ABP). Then seven (07) items are developed, and sized in such a way that they describe the underlying reality of the interaction of project achievement based on the implementation of project-based learning (ABP). Therefore, the questionnaire used to establish the level of knowledge and motivation was applied after the use of the project-based learning (ABP) tool to the mathematical calculation students described in Table 2.

Table 2. Motivation questionnaire to evaluate the use of project-based learning (ABP) by mathematics students studying Information and Communication Technologies (ICT)

Questions	A lot	Quite	Something	A bit	Nothing
The project turned out to be a very interesting academic activity.					
I felt tense and/or nervous during the execution of the project.					
My level of commitment was high.					
I am satisfied with my performance in the execution of the project.					
After working on the project, I felt competent.					
These types of activities are attractive and motivating.					
The execution of the project strengthened my ties with my project colleagues.					

2.8 Resources Used

The resources used to carry out the research include statistical software for data processing and Excel for creating graphs.

2.9 Time

The study was carried out during the year 2022, where the project-based learning strategy combines the use of an online platform to support face-to-face classes. This situation has been a product of the adaptation to the in-person modality after the lifting of health restrictions after the pandemic.

2.10 Procedure

The project will cover several stages, from the choice of the topic to the project formulation, execution, and final delivery of a PowerPoint product. This final delivery summarizes the most relevant aspects of the project, the analysis of the situation presented, and the final reflection. After the presentation of the product, a self-assessment and peer evaluation was carried out to introduce corrections and modifications in its progress and establish the final grade of the project.

2.11 Choice of Topic

One of the most important stages of the project is the choice of the topic, which must be motivating and of current interest, and the use of methodology for project-based learning, where the application of mathematical competencies based on the management of databases arises using ICT appropriately. The interest lies in the fact that when reviewing information from public organizations, students structure the data required to build equations that allow them to calculate the maximum production values in sectors of economic interest for the country using derivation techniques (differential calculus).

2.12 Development of the Theme

Once the topic is selected, students are provided with basic documentation of what the project entails and covers. Guiding questions are posed to develop the topics to be investigated, establish the background, and develop strategies to achieve the final objective. This is represented by the understanding of the assigned topic with the use of ICT for the search for information in public organizations and the construction of mathematical equations for maximum production (application of differential calculus).

For the execution of the project, groups will be formed based on compatibilities between students to promote links of cooperation. These students will analyze the data, use mathematical tools to construct differential equations, apply derivation rules included in the current curriculum, and deliver a final PowerPoint product with the statistical results using graphs, answers, and conclusions.

Before executing the project, the groups must present a work plan that includes project contents, objectives, research models, data collection methods, classification, analysis and interpretation of data, and presentation of results. It is worth mentioning that students have their own autonomy in the search, analysis, and contrast of the required information. The role of the educator is to guide, clarify doubts, promote self-evaluation, and make corrections that facilitate the achievement of objectives. The final interest is to comply with the only requirement; the data collected comes from official entities in charge of monitoring the pandemic in Spain.

2.13 Data Analysis

The results corresponded to the qualitative parameters generated from the IMI questionnaire to determine the degree of satisfaction, which were analyzed using descriptive statistics comparing the average values obtained for each item evaluated in the questionnaire. In addition, comparisons are made of the percentage of students capable of meeting the competencies achieved through the learning project based on the development of mathematical competencies, comparing this metric with the level of performance and expectations prior to its use.

3 Results

The results show that project-based learning (ABP) strategies in the field of mathematics in the context of an information technology program were positive in improving academic performance. Such a reality may apply due to an increase in student's interest in learning mathematics. As described in the findings, when determining a percentage of appreciation of 56.76% in the students who completed the project with ABP implementation compared to the initial 41.79%, there was only a negative evaluation of 13.92% of the students, as seen in Figure 2.

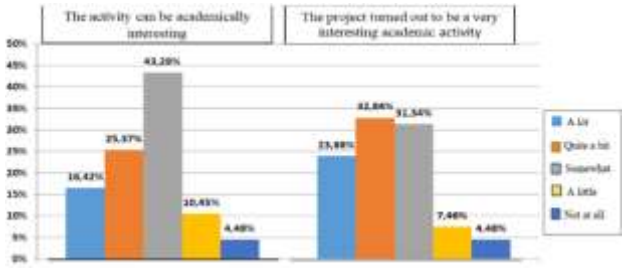

Fig. 2: Level of interest in undertaking mathematics learning projects among ESPOCH students supported by the use of ICT

One of the factors that improves student performance, particularly in the field of mathematics, is reducing stress levels. In this regard, Figure 3 shows that the tension levels were reduced from 44.78% to 31.35%. However, 38.81% of students still report feeling tense or nervous during the execution of projects, even when using different learning tools such as ABP.

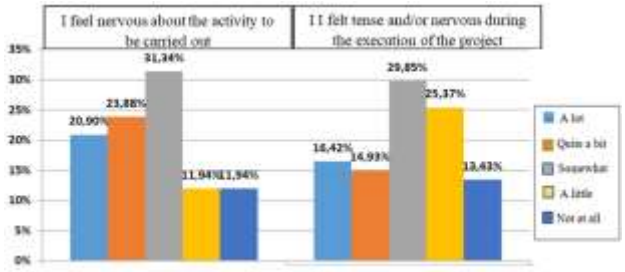

Fig. 3: Level of tension when undertaking mathematics learning projects among ESPOCH students supported by the use of ICT

Greater interest and a reduction in tension levels improve competence in the field of mathematics, as reflected in Figure 4. However, it is observed that mathematical competencies at the level of positive assessment did not change significantly, with values of 58.21% and 58.31% before and after the use of ABP, while the negative evaluation was 13.44%.

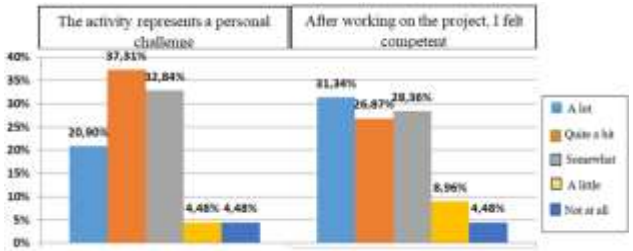

Fig. 4: Level of mathematical competence through the use of learning projects among ESPOCH students supported by the use of ICT

Among the skills that you want to develop beyond the competencies of the academic area is collaborative work. The results presented in Figure 5 show that the use of ABP promoted this type of skill by observing after the execution of the project a positive evaluation of 58.21%, compared to the previous evaluation of 32.84% with a negative perception of 19.30%. Indicating that the efforts. There is still much to be done to educate students about the value of teamwork.

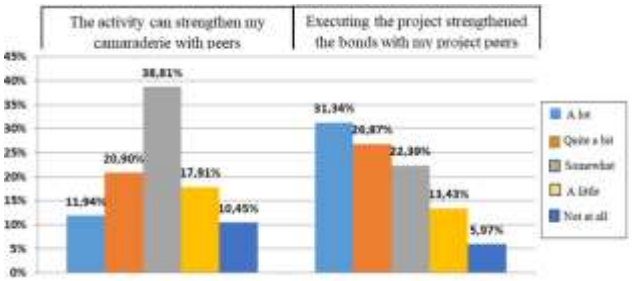

Fig. 5: Capacity for collaborative work through mathematics learning projects among ESPOCH students supported by the use of ICT

Achieving the desired objectives is not possible if the educational material is not understood. Fortunately, Figure 6 shows that 59.71% of the students have a positive evaluation of the educational material provided, while 14.93% have a negative evaluation of it. This prevents them from successfully developing the assigned project.

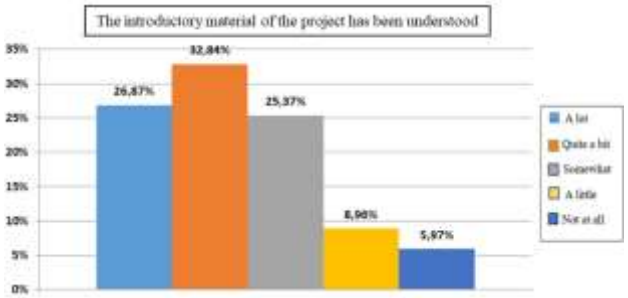

Fig. 6: Understanding the educational material used in mathematics learning projects among ESPOCH students supported by the use of ICT

The achievement of the objectives is not possible without the commitment of the students to carrying out the assigned tasks, which is highly associated with motivation and interest in learning mathematics. Fortunately, Figure 7 shows that 64.1% of the students were highly committed to completing the project, while 13.44% showed a negative attitude towards completing the tasks.

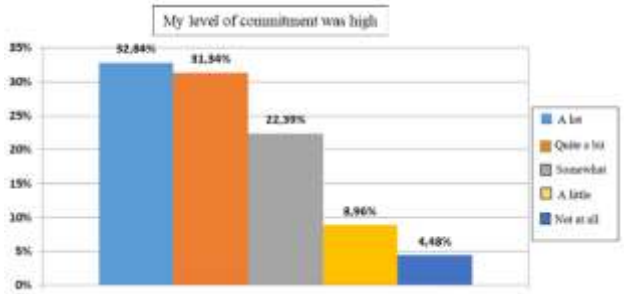

Fig. 7: Level of commitment to learning mathematics through the use of learning projects among ESPOCH students supported by the use of ICT

Improvements in mathematics learning are not only observed in academic performance but can also be perceived in the student's own opinion of their performance. In this line of thought, Figure 8 determines that 59.70% of the students were satisfied with the performance achieved, while 14.83% expressed dissatisfaction with the performance shown during academic activities.

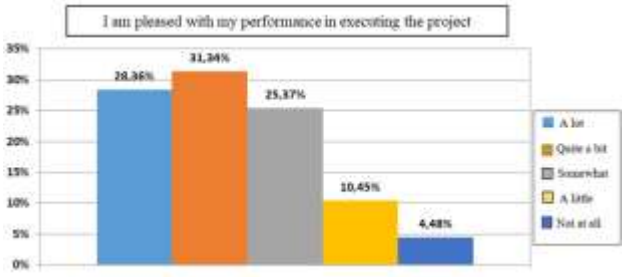

Fig. 8: Perception of student performance after the use of learning projects at ESPOCH supported by ICT management

All the positive aspects observed in a large part of the students in relation to better performance, interest, willingness to work as a team, and commitment are only possible if there is a level of motivation to carry out the project. In this sense, Figure 9 stipulates that 54.20% of the students showed high motivation for the execution of the project, and only 10.45% stated that they were not willing to undertake the assigned tasks.

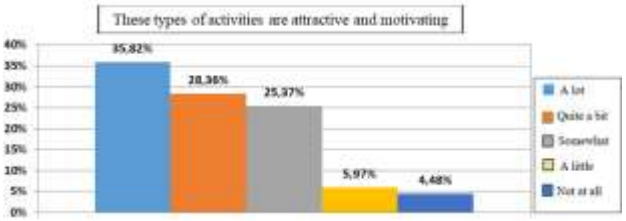

Fig. 9: Level of motivation for learning mathematics among ESPOCH students through the use of a project supported by ICT management

3.1 Level of Achievements Achieved

Greater interest, understanding, and motivation should be reflected in a high level of achievement in relation to the academic objectives set.

Table 3. Level of achievement achieved after the use of a learning project among ESPOCH students supported by ICT management

Assessment	Comprehension	Use of ICT	Construction of equations
Correct	67.16	65.67	62.69
Moderately correct	22.39	28.36	29.85
Incorrect	10.45	5.97	7.56

Regarding the above, it was observed that 57.60% adequately understand the contents taught, while 65.76% adequately use ICT to obtain statistical information for the construction of mathematical equations, which they do correctly in 62.69% of the cases.

However, Table 3 also shows that 10.45% of students do not understand the content taught, which leads to incorrect use of ICT in 5.97% of cases. Therefore, 7.56% construct mathematical equations in an inappropriate manner for the analysis and interpretation of information. In essence, a significant impact achieved by students when using the ABP methodology can be generalized to the achievements achieved by students in the evaluation of the level of understanding, applicability of ICT, and implementation of mathematical demonstrations correctly or, failing that, moderately correct (Figure 10).

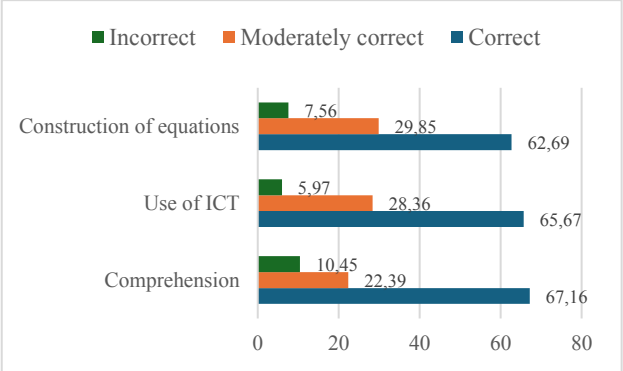

Fig. 10: Comparison between dimensions of competencies achieved among ESPOCH students supported by ICT management

A higher level of performance in mathematics learning, added to the use of information technologies, resulted in better academic performance of the students, as was observed in a slight increase in average grades, an increase in the number of passing grades, and a reduction in failures, a scenario shown in Table 4.

Table 4. Performance of mathematics students in the Information and Communications Technologies (ICT) program after the use of project-based learning strategies

Use of ABP	Average grade	Approved (%)	Failed (%)
No	10.90	66.66	33,34
Yeah	11.20	75.00	25.00

The interpretation of the performance obtained by the students when using the ABP methodology is satisfactorily described by increasing the average grade, the increase in approval in evaluations by 8.3 percentage points, and the decrease in failures by 8.3 percentage points at a comparative level with the group of students who did not use ABP (Figure 11).

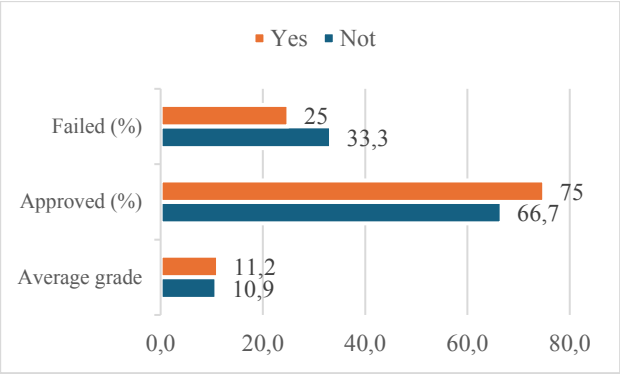

Fig. 11: Comparison between categories of use in the ABP methodology among ESPOCH students supported by ICT management

4 Discussion

The present contribution focuses on the experience of students of the Information and Communications Technologies (ICT) program at ESPOCH, which focuses on the application of ICT for project-based learning of mathematics (ABP). In which the impact of ABP on the development of digital skills, collaborative work, and student motivation is analyzed. Therefore, it is possible to identify the main challenges and opportunities for the integration of ICT in mathematics teaching.

The ABP methodology, according to the findings in this study, allows ICT students to consolidate their experience through the practical application of mathematical knowledge in projects with real data. As well as being a methodology adaptable to the needs of students with a flexible approach for the development of essential skills, problem-solving, consolidation of teamwork, and creativity.

At this point, the degree of innovation of this study is defined by combining different methodologies: the integration of problem-based learning (ABP) with the construction of differential equations, which allows students to develop problem-solving and critical thinking skills. Likewise, it consolidates the experience by concatenating the fundamentals of the career under study with mathematical demonstrations for solving real problems.

Being able to undertake and understand the level of stress in the development of learning projects in the area of mathematics among ESPOCH students, with the support of ICT, is essential to motivating interest in achieving meaningful learning. Authors such as [24] state that ABP seeks to take advantage of the innate potential of students with the aim of training them to be responsible people with a high level of motivation towards the acquisition of knowledge. Promoting the definition of a project as an act carried out in a social environment in order to carry out an enthusiastic activity with a specific purpose, consolidating their interest in the study of mathematics.

Regarding the level of tension developed when undertaking mathematics learning projects among ESPOCH students supported by the use of ICT. In this context, considering the contributions of [25], where they state that ABP aims to invite students to search for sources or methods to obtain answers in the project development phases. This allows them to promote communication and coordination skills in an inclusive learning context based on their interests and abilities. This has been demonstrated in research with a significant percentage of students who reported that using ABP in academic activity turns out to be very interesting.

In this regard, some authors, such as [26], point out that the low academic performance of students in mathematics, in addition to motivational issues such as anxiety, occurs in a context in which fears of having to abandon previous knowledge arise and are present in learning situations.

In the study by [27], a meta-analysis of numerous socio-emotional development programs was conducted, finding that these programs achieved an increase in indices related to general well-being, interpersonal relationships, learning, commitment, academic performance, and mastery of the content, as well as a decrease in depressive symptoms.

With respect to the level of competencies developed through the use of learning projects among ESPOCH students supported by the use of ICT. The findings in this study coincide with those found by [28], who indicate that it can be concluded that ABP and ICT are excellent learning strategies for the acquisition of mathematical knowledge in students with learning difficulties. Given that the initial test showed 27% of students with low performance and 7% with superior performance, in the final test, it turned out to be 83%.

Furthermore, it is noted that project-based learning combines the development of cognitive aspects with the ability to analyze and interpret data, [29]. In this case, the author points out that when evaluating a group of engineering students, they successfully searched for information through the identification and application of data. However, they showed an important weakness when analyzing and interpreting tables and graphs to conclude on the importance of the topic analyzed.

The higher level of competence observed in the mathematical calculation students of the ESPOCH

information technology program coincides with the results found by [30], who indicate that Cuban students who used ABP as a learning strategy showed a medium to high level of competence in aspects related to the depth of mental processes. These authors point out that ABP seeks for the student to use their own reasoning and procedures to promote the development of skills and abilities based on their own interests.

Regarding consolidating collaborative work capabilities through learning projects in mathematics among ESPOCH students supported by the use of ICT. It implies the need to adopt pedagogical strategies that generate meaningful and collaborative learning in students to solve everyday problems, as pointed out by [31]. In correspondence with what was proposed by [32], who maintains the main objectives in ABP: to promote team and collaborative work, the development of capacities, skills, and values, to generate a motivating environment, and to develop self-learning and creative thinking.

The level of understanding of the educational material used in mathematics learning projects among ESPOCH students is supported by the use of ICT. The aforementioned results coincide with those reported by [33], where it was observed that the majority of participants consider them adequate or very suitable. In fact, more than 85% of those surveyed believe that the resources facilitate understanding, learning, and reinforcement of the topic addressed, which defines types of abstract data similar to those prevalent in mathematics learning.

Therefore, [34] asserts that the selection, creation, and use of educational materials, in addition to strategies and other essential aspects of the teaching-learning process, are decisive for achieving the proposed objectives. It is fundamental that the resources created must be efficient and, above all, must not be prone to errors, and that the language of interaction between students and devices must be in terms of words, phrases, and concepts familiar to students.

By establishing the level of commitment to mathematics learning through the use of learning projects among ESPOCH students supported by the use of ICT. Authors such as [35] point out that learning from solving real-world problems has been identified as a relevant aspect within the teaching of mathematics education and has begun to be used more regularly, with an emphasis on the mathematics teaching process. This increasing increase is offered based on a series of didactic proposals that try to work on the reasoning through problem-solving, which enhances the level of commitment to learning the subject.

Corresponding to [36], he compares the statement that success in ABP is due to its ability to demystify mathematics and bring it closer to real-life problems and, therefore, to students. It is considered an innovative methodology that makes use of new technologies and involves the active participation of students in the process of construction and acquisition of mathematical knowledge, based on the premise that they are capable of doing so.

In relation to the perception of student performance after the use of learning projects at ESPOCH supported by ICT management, it is based on the level of enthusiasm, commitment, and motivation that the students have shown during the project. This agrees with what was pointed out by [37], who affirms that the high motivation of students to learn through this methodology (ABP) is closely related to their positive self-perception of what they learned during the development of the activities.

It is stated in [38] that PBL has produced positive results in all areas of the curriculum, including mathematics. Various studies have compared this methodology with the traditional class and have demonstrated its advantages in very diverse aspects, such as academic performance, the acquisition of competencies and skills, and the improvement of student satisfaction.

Finally, the level of motivation for learning mathematics exhibited by ESPOCH students through the use of a project supported by ICT management demonstrates that ABP has a broad application approach because, in schools, it improves ways to use the innate potential of students and prepares them to be responsible citizens motivated towards learning. Indeed, this is indicated by [39], a statement that is corroborated by [40], who mentions that the stimulation received with this strategy allows students to feel motivated and committed to the development of their activities by autonomously strengthening their learning.

The levels of achievement achieved in this study align with the findings reported by [28], [40], who, after the implementation of ABP observed an improvement in performance. This has confirmed that the application of this methodology partially overcomes the learning difficulties in teaching mathematical operations and improves the academic performance of students in mathematics, as demonstrated by the results of the courses where this strategy was implemented.

The success of ABP as a learning strategy is based on the improvement of the work environment and the collaborative spirit of the methodology, which are reflected in the performance of the students. In this regard, the results obtained by [37], [40] confirm this: These authors, when using ABP in basic-level courses, found that the level of organization of the projects, the size of the groups, and the design of the assigned tasks were correct from the perspective of the students, which has led to results valued in greater motivation for the execution of the project.

5 Conclusions

ICT allows students to use real information for the development and execution of mathematical equations, which translates into a greater appreciation of their use, increasing motivation and interest in learning them, which manifests itself in better academic performance.

Improvements in academic performance were evident in the correct use of ICT for the construction of mathematical equations. These equations are formulated for resolution using derivation rules to allow interpretation of the behavior of different sectors of economic interest in Ecuador. The above, through the use of ICT, promotes the proper management of databases and the ease of obtaining information on the majority of the websites of Ecuadorian public institutions.

The key to improving mathematics learning through the use of ICT resided in the commitment and motivation of the students, which was reflected in a higher level of competencies in the development of skills and abilities in the field of mathematics. It was possible to verify the significant increase in grades since the use of ABP was applied to mathematics learning.

References:

[1] Ratheeswari K. Information Communication Technology in Education. Journal of Applied and Advanced Research, 2018: 3(Suppl. 1) S45-S47. *Proceedings of the Conference on "Recent Trend of Teaching Methods in Education"* Organised by Sri Sai Bharath College of Education Dindigul-624710, Tamil Nadu, India. p.1-3. ISSN: 2519-9412. Phoenix Research Publishers. https://doi.org/10.21839/jaar.2018.v3iS1.169 .

[2] Moreno C., Carretero Ma R., Sáenz-Rico B., Rumayor L. Gamification-Education: the power of data. *Teachers in social networks.* RIED-Revista Iberoamericana de Educación a Distancia, vol. 27, núm. 1, p.1-14. 01 Enero 2024. https://doi.org/10.5944/ried.27.1.37648.

[3] Taha A. *The Wave of Change in The Methods of Education Brought by Social Media: A Case Study of TikTok's Potential for Educational Content Creators*. Salzburg, 30.07.2021. p.1-95, [Online]. https://eplus.uni-salzburg.at/obvusbhs/content/titleinfo/7315307/full.pdf (Accessed Date: April 21, 2024).

[4] Martin C. and Bertrum H. MacDonald. *Using interpersonal communication strategies to encourage science conversations on social media.* PLoS One. 2020; 15(11): e0241972, p.1-32.Published online 2020 Nov. 10. DOI: 10.1371/journal.pone.0241972.

[5] Yogesh K. Dwivedi, Elvira Ismagilova, D. Laurie Hughes, Jamie Carlson, Raffaele Filieri, Jenna Jacobson, Varsha Jain, Heikki Karjaluoto, Hajer Kefi, Anjala S. Krishen, Vikram Kumar, Mohammad M. Rahman, Ramakrishnan Raman, Philipp A. Rauschnabel, Jennifer Rowley, Jari Salo, Gina A. Tran, Yichuan Wang. Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management.* Vol. 59, August 2021, 102168, p.1-37. https://doi.org/10.1016/j.ijinfomgt.2020.102168.

[6] Arfa Afzal, Saima Khan, Sana Daud, Zahoor Ahmed, Ayesha Butt. Addressing the Digital Divide: Access and Use of Technology in Education. June 2023. *Journal of social sciences review*, vol. 3, n° 2, p. 883-895. DOI: 10.54183/jssr.v3i2.326.

[7] Maninder Singh, P.S. James, Happy Paul, Kartikeya Bolar. Impact of cognitive-behavioral motivation on student engagement. *Heliyon.* Vol. 8, Issue 7, July 2022, e09843, p.1-9. https://doi.org/10.1016/j.heliyon.2022.e09843.

[8] Mzomwe Yahya Mazana, Calkin Suero Montero, Respickius Olifage Casmir. Investigating Students' Attitude towards Learning Mathematics. *International Electronic Journal of Mathematics Education.* e-ISSN: 1306-3030. 2019, Vol. 14, No. 1, p. 207-231. https://doi.org/10.29333/iejme/3997.

[9] Stella Timotheou, Ourania Miliou, Yiannis Dimitriadis, Sara Villagrá Sobrino, Nikoleta Giannoutsou, Romina Cachia, Alejandra Martínez Monés, and Andri Ioannou. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Educ. Inf. Technol. (Dordr).* 2023; vol. 28, n° 6: p. 6695–6726. https://doi.org/10.1007%2Fs10639-022-11431-8.

[10] D Fisher, Yaya S. Kusumah, Jarnawi Dahlan. Project-based learning in mathematics: A literatur review. October 2020. *Journal of Physics: Conference Series*, Vol. 1657, *The 2nd International Seminar on Applied Mathematics and Mathematics Education (2nd ISAMME)* 2020 5 August 2020, Cimahi, Indonesia, Vol. 1, 012032, pp.1-7. https://doi.org/10.1088/1742-6596/1657/1/012032.

[11] R Robin W. Erwin, Jr. Data Literacy: Real-World Learning Through Problem-Solving With Data Sets. *American Secondary Education.* Vol. 43, No. 2 (Spring 2015), pp. 18-26. Published byDwight Schar College of Education, Ashland University, [Online]. https://www.jstor.org/stable/43694208 (Accessed Date: April 23, 2024).

[12] Ulises Salinas-Hernández, Zeger-jan Kock &Birgit Pepin. Mathematics students' self-reported resources used for solving real-life problems in a challenge-based modelling course. *International Journal of Mathematical Education in Science and Technology*, pp. 1–26. 27 Mar 2024. https://doi.org/10.1080/0020739X.2024.2327558.

[13] Inca C.L., Evelyn Geovanna Inca Balseca, Julio Cesar Morocho Orellana, Andrés Fernando Morocho Caiza, Franklin Marcelo Coronel Maji, Lizeth Fernanda Silva Godoy. Project-based learning (ABP) in the teaching of mathematics in the context of computer programming. (2023). *Journal of Namibian Studies: History Politics Culture*, Vol 33: Special Issue 2, pp. 2051–2069. https://doi.org/10.59670/jns.v33i.830.

[14] Quinapallo-Quintana A. M. & Baldeón-Zambrano A. X. Project-based learning. January 2024. *International Research Journal of Management IT and Social Sciences*. vol 11, n° 1: pp.58-65. https://doi.org/10.21744/irjmis.v11n1.2415.

[15] Isaza Maya, Y. & Escobar Londoño J. Didactic And Methodological Strategies In Mathematics Education: A Systematic Review. *Migration Letters.* Vol. 20, No: S2 (2023), pp.1253-1266. ISSN: 1741-8984. e-ISSN: 1741-8992, [Online]. https://migrationletters.com/index.php/ml/article/download/7875/5084/20583 (Accessed Date: April 23, 2024).

[16] Jara Quito, D. M., Martínez Sierra, R. & Orúe López, A. (2023). Critical analysis about the exit profile of theecuadorian high school graduate. A look from a project-based learning method. *MLS-Educational Research,* 7(1), pp. 94-110. DOI: 10.29314/mlser.v7i1.890. *Letters.* Vol. 20, No: S2 (2023), pp. 1253-1266. ISSN: 1741-8984, e-ISSN: 1741-8992.

[17] Nur Afiqah Zakaria, Fariza Khalid. The Benefits and Constraints of the Use of Information and Communication Technology (ICT) in Teaching Mathematics. Department of Learning & Teaching Innovations, Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, Malaysia. *Creative Education*, Vol.7 No.11, July 2016, pp. 1537-1544. http://dx.doi.org/10.4236/ce.2016.711158.

[18] Vale Isabel & Barbosa A. Active learning strategies for an effective mathematics teaching and learning. March 2023. *European Journal of Science and Mathematics Education*, vol. 11, n° 3, pp. 573-588, https://doi.org/10.30935/scimath/13135.

[19] Lu Zhang and Yan Ma. A study of the impact of project-based learning on student learning effects: a meta-analysis study. *Front Psychol*., 2023 Jul 17; 14: 1202728, pp. 1-14, https://doi.org/10.3389%2Ffpsyg.2023.1202728.

[20] Jinfa Cai. What Research Says About Teaching Mathematics Through Problem Posing. *Éducation et didactique.* Vol. 16-n° 3, pp. 31-50. https://doi.org/10.4000/educationdidactique.10642.

[21] Kirby J. L. D., Danielle Rencell C. Caraan, Delon Ching. Effectiveness of Realistic Mathematics Education Approach on Problem-Solving Skills of Students. June 2023. *International Journal of Educational Management and Development Studies*. Vol. 4, n° 2, pp. 64-87, https://doi.org/10.53378/352980.

[22] Cruz S, Viseu F and Lencastre JA (2022) Project-Based Learning Methodology as a Promoter of Learning Math Concepts: A Scoping Review. *Front. Educ.*, Vol. 7:953390, pp. 1-11. https://doi.org/10.3389/feduc.2022.953390.

[23] Villena-Martínez, E.I., Rienda-Gómez, J.J., Sutil-Martín, D.L. et al. Psychometric properties and factor structure of a motivation scale for higher education students to graduate and stimulate their entrepreneurship. *International Entrepreneurship and Management Journal.* June 2024, Volume 20, Issue 2, pp. 1-28. https://doi.org/10.1007/s11365-024-00948-8. (Accessed Date: June 23, 2024).

[24] Lozano A, López R, Pereira FJ, Blanco Fontao C. Impact of Cooperative Learning and Project-Based Learning through Emotional Intelligence: A Comparison of Methodologies for Implementing SDGs. *Int J Environ Res Public Health. 2022. Dec 17; 19(24):16977, PMID: 36554857; PMCID: PMC9778663*, pp.1-17. https://doi.org/10.3390/ijerph192416977.

[25] Ukackė, Vilma, Aida Olivia Pereira de Carvalho Guerra, Dorothea Ellinger, Vânia Carlos, Saulė Petronienė, Lina Gaižiūnienė, Silvia Blanch, Anna Marbà-Tallada, and Andrea Brose. 2022. "Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL", *Sustainability*, 14, no. 21: 13955, pp.1-31. https://doi.org/10.3390/su142113955.

[26] Suren, N., & Kandemir, M. A. (2020). The effects of mathematics anxiety and motivation on students' mathematics achievement. *International Journal of Education in Mathematics, Science and Technology*, vol. 8, n° 3, pp. 190-218, [Online]. https://files.eric.ed.gov/fulltext/EJ1263622.pdf (Accessed Date: April 26, 2024).

[27] Durlak J.A., Roger P. Weissberg, Allison B. Dymnicki, Rebecca D. Taylor, Kriston B. Schellinger. The Impact of Enhancing Students' Social and Emotional Learning: A Meta-Analysis of School-Based Universal Interventions03 February 2011, Vol. 82 n° (1), pp. 405-432. https://doi.org/10.1111/j.1467-8624.2010.01564.x.

[28] Yetti Ariani, Suparman Suparman, Yullys Helsa, Melva Zainil, Rahmatina. ICT-Based or -Assisted Mathematics Learning and Numerical Literacy: A Systematic Review and Meta-Analysis. March 2024.*International Journal of Information and Education Technology*, vol. 14, n°3, pp. 382-397. 10.18178/ijiet.2024.14.3.2060.

[29] Yu H. Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon.* Vol. 10, Issue 6, 30 March 2024, e27706, pp. 1-9. https://doi.org/10.1016/j.heliyon.2024.e27706.

[30] Rocha H. & Babo A. Problem-solving and mathematical competence: A look to the relation during the study of Linear Programming. March 2024. *Thinking Skills and Creativity*, vol. 51, n° 2:101461, p.1-14. https://doi.org/10.1016/j.tsc.2023.101461.

[31] Rehman N., Wenlan Zhang, Amir Mahmood, Muhammad Zeeshan Fareed & Samia Batool.Fostering twenty-first century skills among primary school students through math project-based learning. *Humanities and Social Sciences Communications*, Vol. 10, Article number: 424, pp.1-12, 18 July 2023. https://doi.org/10.1057/s41599-023-01914-5.

[32] Obi, M. Pedagogical Strategies for Enhancing Online Collaboration. *Journal of Online and Distance Learning*, Vol. 3, Issue No.1, pp. 41-52, February 2024. https://doi.org/10.47941/jodl.1692.

[33] Rybak A. Effectiveness of teaching and learning in technology-supported mathematics education. *Journal of Physics: Conference Series*, vol. 1946, n° 012004. ICon-MaSTEd 2021. pp. 1-18. https://doi.org/10.1088/1742-6596/1946/1/012004.

[34] Saleem A., Huma Kausar, Farah Deeba. Social Constructivism: A New Paradigm in Teaching and Learning Environment. Farah deeba's Lab: Institution: Bahauddin Zakariya University. December 2021. *Perennial Journal of History*. Vol.2, N° 2: pp. 403-421. https://doi.org/10.52700/pjh.v2i2.86.

[35] Liljedahl, P., Santos-Trigo, M., Malaspina, U., Bruder, R. Problem Solving in Mathematics Education. In: Problem Solving in Mathematics Education. *ICME-13 Topical Surveys*. Springer, Cham. Online ISBN: 978-3-319-40730-2, pp. 1–39. 28 June 2016. https://doi.org/10.1007/978-3-319-40730-2_1.

[36] Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of

the literature. Improving Schools, 19(3), pp. 267-277. https://doi.org/10.1177/1365480216659733.

[37] Pradanti P. and Moh. Rikza Muqtada. Students' perceptions on learning, motivation, and performance through project-based learning: undergraduate students' case. April 2023. PYTHAGORAS *Jurnal Program Studi Pendidikan Matematika*, Vol. 12, N°1: pp.16-26. https://doi.org/10.33373/pythagoras.v12i1.5011.

[38] Kusmaryono, I. and Basir, M.A. Learning media projects with YouTube videos: a dynamic tool for improving mathematics achievement. April 2024. *International Journal of Evaluation and Research in Education (IJERE)*, Vol. 13, N°.2:934, pp. 1-9. p-ISSN: 2252-8822, e-ISSN: 2620-5440. http://doi.org/10.11591/ijere.v13i2.26720.

[39] Sintema E. J. & Mosimege M. High School Students' Beliefs about Mathematical Problem Solving: A Cluster Analysis. *Mathematics Teaching Research Journal.* Early Spring, 2023. Vol 15 no 1, pp. 68-83, [Online]. https://files.eric.ed.gov/fulltext/EJ1391467.pdf (Accessed Date: July 5, 2024).

[40] Soto S.T., Julio Chumbay Guncay, Marisol Estefanía Calle. Strategies and techniques to enhance student motivation in the EFL classroom. In book: Where Motivation and Learning Meet: Bringing Key Concepts, Research Insights, and Effective Practices Together into the Language ClassroomEdition: 1Chapter: 5Publisher: Editorial UTMACH. March 2024. pp. 1-61. ISBN: 978-9942-24-184-9. http://doi.org/10.48190/9789942241849.5.

Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

The authors contributed equally to the present research, at all stages from problem formulation to final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of interests

The authors have no conflicts of interest to declare.