Project-Based Learning in the Perception of Stem Subjects and the Improvement of Hard and Soft Skills in University Students

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Abstract

Current educational scenarios characterized by scientific and technological development demand quality education, in this sense, it is necessary that students develop skills, abilities, and capacities that allow them to respond to the social problems and needs they will face in their working and professional life. Thus, the researchers analyzed the importance of the application of PBL Project Based Learning through the use of PhET simulators on the perception of STEM subjects and the development of hard and soft skills. Initially, a survey form was applied to 130 students of Agronomy, Agroindustry, and Veterinary Medicine in the first cycle of the State University of Bolivar, to measure the perception of STEM and the development of their hard and soft skills. To analyze the relationship, two working groups were created, G1 to which the PBA was applied, and G2 to which the normal methodology was applied. The results of the Mann-Whitney U statistical test show differences between the statistical means of the control groups and its p-value of less than 0.05 indicates a correlation between the variables, on the other hand, the student's perception improved significantly after the PBL intervention on STEM, thus increasing the student's knowledge and acceptance in mathematics, science, and engineering.

Keywords:STEM disciplines, PhET labs, Project Based Learning.

DOI Number: 10.14704/NQ.2022.20.16.NQ88066 NeuroQuantology2022; 20(16):643-656

1. INTRODUCTION

An increasingly dynamic, globalized, competitive society characterized by the volatility of its innovations, requires prepared, competent professionals with soft and hard skills who can face new challenges and complex problems (Lane et

al., 2022). Educational contexts must have the ability to prepare future professionals in the best way, through new methodologies that achieve a higher level of preparation and understanding of the world and its phenomena, for which it is necessary that from the first years of education of the student creative thinking is formed, curious, there is knowledge (López-Díaz & Peña, 2022).

In this line, Tsupros et al (2009) mention that "A knowledge-based economy is driven by constant innovation, motivated by qualified human resources and equipped with skills in the field of science, technology, engineering and mathematics" (p. 4), the need to develop professionals with a comprehensive training with knowledge in different areas to achieve high levels of optimal competence(Santilla, 2017),(Santillan, 2019).

To develop these skills it is necessary to train students under new didactic approaches that achieve the development of competences because current educational approaches focus on "the transmission of content", (Tomperi, et al., 2022)where the use of expository methods and activities that promote memorization and repetition of content predominates(Lima,2021). Teaching is based on the "authority" (or authoritarianism) of the teacher, he possesses the knowledge, makes the decisions, and defines the teaching and evaluation strategies(Gonzaga, 2005).

STEM disciplines (Science, Technology, Engineering, Mathematics) are presented as transversal tools to face contemporary challenges, (Yaser, 2022)because it achieves that students have trained with an integrative approach(Lozada, 2020), that is, with skills to function in current contexts, as mentioned by García-Cartagena et al (2017) STEM disciplines "From an approach that privileges the teaching of integrated sciences with emphasis on their applications in the real world" (p. 38), prepare students for real contexts that society presents with increasing demands (Santillan,2022).

Also, STEM from its origins was based on an approach of constructivist theory, which assumes (Sullivan & Bers, 2017)its premises to establish that the student builds and reconstructs his knowledge by interacting with the world around him, from this constant interaction knowledge is developed and internalized from the experiences and interactions of the individual with his environment (Granja, 2016). Hence, learning is understood as a process where multiple variables converge that influence in a greater or lesser way depending on the individual who experiences it and the correlation between it and the medium on which it is returned (Pinto-Ladino & Castro-Bello, 2019).

According to Schwab (2016), the fourth industrial revolution entails transformations in areas such as artificial intelligence, robotics, the internet of things, autonomous vehicles, 3D printing, nanotechnology, Big data, materials science, energy storage, and quantum computing, as the areas with the greatest future and that will revolutionize society (Santillan, 2021), in this sense, which proposes a restructuring of the labor needs that society demands(Molina,2022a), so it takes more strength the skills related to the fields of STEM that new professionals must have what means a future change for the entire educational system that must be able to develop professionals for these new environments.(Botella, López, Rueda, & Forte, 2020)

On the other hand, the STEM approach promotes the development of skills related to problem solving, teamwork, evaluating scientific evidence, and most importantly developing skills in the understanding of the world around them to generate creative solutions to problems that can be

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generated within society (Cabezas,2021). In this sense, education must be constantly evolving to offer didactic models, learning strategies, active methodologies, and in general new constructs and strategies to achieve the development of knowledge, skills, and competencies in students (Brow, 2016),(Sánchez-Harvey et al., 2016)

Therefore, this approach aims to be an ideal didactic methodological resource for the construction of knowledge, and the development of essential skills today to face the different fields and situations that arise daily (Coello-Pisco, et al., 2018). This educational model seeks to enhance the capabilities of students so that they have the necessary skills to develop and face new job challenges.

Therefore, the importance of STEM disciplines within the development of professionals with greater capacity to face the new scenarios characterized by the volatility of innovation and technological advances in a constant way, which restructure society and its operation, on the other hand, is an approach that by its characteristics develops the student integrally, with problem-solving skills that arise in their real life.(Hubinský, Legény, & Špaček, 2022)

The term STEM has been implemented for many years in countries such as South Korea, Australia, France, Great Britain, Germany, Singapore, China, and countless other countries for its characteristics and contributions to educational processes (Gómez-Navarro et al., 2020). In the same way, in the United States, to promote STEM education, there have been fundamental reforms and changes in educational instances to introduce these disciplines as transversal elements by the year 2010 (Molina,2015).

In the same way, the term STEM takes force in South American countries and especially in Ecuador, through initiatives of the Ministry of Higher Education, Science, Technology and Innovation (SENESCYT); the Chamber of Small and Medium Enterprises of Pichincha; the Ministry of Education and the National University of Education (UNAE) in 2018 present a project called STEM Coalition Ecuador, that in the words of these institutions mention the importance of not understanding the subjects separately(Molina,2022), but on the contrary as tools that allow children to be creative, innovate and have the ability to solve problems (Secretariat of Higher Education, Science, Technology and Innovation, 2018). STEM disciplines as an educational strategy to achieve better results within educational processes are the following:

- Abstraction skills are developed within students through activities related to the analysis and synthesis of different concepts and elements, from graphic or textual information which students must read and assimilate to reach a process of internalization and abstraction of such contents to perform these activities.(Barragán-Moreno & Guzmán-Rincón, 2022)
- Logical thinking is encouraged because it incorporates activities related to technology such as programming and all the elements it brings, that is, the student begins to develop activities where mathematical reasoning is encouraged and programming patterns are followed, the same ones that are sequential and needs a certain level of logical thinking (Ismail, Zaman, & Mohammad, 2022).
- In the same way, students encourage critical thinking since they face problems, and to solve them it is necessary to develop critical thinking to solve these problems, analyzing the different ways of facing the problem (Setyaningsih, Adnan, Ahmad, & Anif, 2021).

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- On the other hand, the leadership of the students is encouraged since they usually work in a group where through interaction they develop leadership skills within their environment (Macancela-Coronel et al., 2020).
- A spirit of competition is fostered since usually working groups are formed to solve a problem raised, so countless groups are in constant competition to solve these problems.
- In addition, when working in groups, students must develop social and collaborative skills to be able to work in groups and in a participatory way to solve problems raised by teachers, which requires that all members of the group contribute from each of their knowledge and skills.
- In the same way, when dealing with a way of working through problems that the teacher poses, students develop the creativity that allows them to solve these problems.
- By developing this activity from an early age in children, it allows them to explore and understand the world in a better way, as well as develop language skills that usually pose the programming languages and computer science that is implemented within these didactic activities (Díaz & Damián, 2019)
- In addition, being activities that are related to first-person experimentation, students internalize knowledge in a better way, since by experimenting they acquire knowledge better and promote a constructivist educational model, through interaction with the world and how to solve these problems (Kolodner, et al., 2003).

STEM due to its interdisciplinary characteristics can be related to multiple didactic methodologies such as PBL project-based learning could be determined as a methodological strategy for the design and programming of systematic activities to solve questions, problems, or challenges that the teacher establishes through the STEM approach(Torras, López, & Carrión, 2021). In this sense, this PBL methodology presents ideal characteristics to promote greater interaction and a leading role on the part of the student because of its integrative, motivating character, it makes it have an active role in the resolution of questions or problems (challenges), through a research process(Kusmin, Isla, & Laanpére, 2018).

The PBL by its characteristics allows the construction of shared knowledge generated from the interaction and the promotion of autonomy (Cabezas, 2019), it is thus that it encourages the evaluation and continuous reflection, improves the interaction between students, encourages analytical thinking, helps the development of knowledge, promotes empowerment and positive emotions in students, (Bosquez, et al., 2018) That is, on the one hand, it fosters soft skills and together hard skills in students(Vogler, et al., 2018).

One of the technologies that are adequately related to STEM disciplines is the use of virtual laboratories based on simulation (Granja, 2017), these tools allow the student to learn new concepts through interaction with them, consolidate knowledge, reinforce concepts and promote autonomous learning guided by the teacher (Mariscal, et al., 2020), are presented as an alternative for educational institutions that do not have the resources or equipment to carry out practices of this type. One of the alternatives widely used by the educational community is the PhET virtual laboratories that are characterized "based on extensive education research and involve students through an intuitive and game-like environment, where they learn by exploring and discovering", (PhET, 2022) and provides a range of options for areas such as mathematics, physics, chemistry,

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Biology, among others, is also characterized by being free which is presented as a significant advantage to other platforms of this type since the users implement must create a user on the platform to have access to its benefits(Santillan, 2013).

II. MATERIALS AND METHODS

The study was taken to the Faculty of Agricultural Sciences, Natural Resources and Environment of the State University of Bolivar, focused on students in the first cycle of their careers in Agronomy, Agroindustry, and Veterinary Medicine, having a total of 130 students, who were invited to participate by filling out an online form at the beginning of the cycle To know what their affinity is on STEM disciplines, of which 57.69% belong to the female sex and 42.30% to the male sex, the form sought to analyze if they were linked to Science, Mathematics, Technology or Engineering, these results allowed to know their profile. It used a survey instrument developed by Bautista-Díaz (2018) that deals with attitudes towards STEM, composed of 32 items of which modifications were made to the form to avoid redundancy in the questions so that the data collection instrument has a short time In response, additionally, items were included that allow knowing the soft and hard skills in the students before the intervention, with a form with 21 items. During the cycle, PBL project-based learning with the use of PhET simulators was applied to 50% of the students surveyed (G1) to determine if the proposed methodology affects the perception they have about STEM subjects and if their soft and hard skills improve after the cycle, to the other 50% (G2) it was used as a control group to determine the difference between those who developed their knowledge under PBL and those who did not. At the end of the cycle, the form was reapplied, to identify the difference in the skills shown before and after.

To determine whether it is a parametric sample or not, the Kolmogorov-Smirnov test was used because it is considered one of the best goodness of fit. Next, to determine if there is a difference in the means and statistical significance between groups G1 and G2 in the improvement of soft and hard skills in the previous studies, the statistical test Mann-Whitney(Chari & Hirisave, 2020)U-test was used, since it allows us to analyze a category variable, against ordinal variables, it will also allow us to compare the sample means and test if they are equal or not, this test realizes a statistical comparison of the mean and determines if there is a difference in the dependent variable for two independent groups.

III. RESULTS AND DISCUSSION

The initial results of the proposed form are set out below.

Table 1 *Results of the survey form at the beginning of the cycle*

Item	Totally agree		I agree		Disagree		Strongly disagree		Total
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	
Mathematics									
Math is easy for me	3	2%	10	8%	42	32%	75	58%	130
I've always had good grades in math	25	19%	29	23%	34	26%	42	32%	130
Sciences									
I understand the sciences well	42	32%	41	32%	34	26%	13	10%	130
I do the science work well	28	22%	34	26%	34	26%	34	26%	130
I would like to work on	45	35%	42	32%	29	22%	14	11%	130

something related to science									
I consider science subjects important for academic development	57	44%	49	38%	16	12%	8	6%	130
Technology									
I like technology	125	96%	5	4%	0	0%	0	0%	130
I have ease to handle technology	105	81%	22	17%	3	2%	0	0%	130
I like to constantly handle technology for the development of academic problems	85	66%	34	26%	7	5%	4	3%	130
I think technology management is very important for my professional future	118	91%	12	9%	0	0%	0	0%	130
I believe that knowing robotics and programming languages contributes to the development of current problems	102	78%	13	10%	6	5%	9	7%	130
Engineering									
I like engineering	65	50%	25	19%	6	5%	34	26%	130
I like to create and innovate	62	48%	28	21%	12	9%	28	22%	130
Soft skills									
I like to actively participate in classes	41	32%	29	22%	34	26%	26	20%	130
I like to work in a team	45	35%	31	24%	20	15%	34	26%	130
I like to lead my group in academic activities	25	19%	23	18%	34	26%	48	37%	130
I like to maintain good communication with my colleagues	41	31%	42	32%	28	22%	19	15%	130
Hard skills									
I find it easy to develop concepts related to the subjects	24	19%	29	22%	21	16%	56	43%	130
I find it easy to develop mathematical operations and exercises	17	12%	22	16%	24	17%	77	55%	130
I believe that I have a good capacity for analysis to solve problems related to the subjects	42	32%	28	22%	24	18%	36	28%	130
I consider myself to possess high analytical thinking	31	24%	24	18%	26	20%	49	38%	130

It is evident that students do not have much affinity for mathematics, so only 2% totally agree that mathematics is easy, and 19% have had good grades in mathematics. Regarding science, 32% understand science

well, 22% adequately carry out science work and 44% consider the science subject important, these results go hand in hand with what was stated by Tirado (2021) which indicates that in The subjects of Sciences it is observed that Chemistry, Physics, and Biology are considered among the most difficult and unpleasant for students, in many cases it is because they are not carried out practically, teachers assume a very conceptual profile among other factors that make them difficult. Concerning technology, it is evident that all the students surveyed have ease in its handling, they consider that technology is important in their professional lives(Zambrano & Zambrano, 2019). In the same way, 50% like engineering, and 48% like to create and innovate.

Regarding the soft skills shown by the students, it is observed that they show greater attachment to teamwork with 35% of respondents who mention being very much in agreement with this form of work, also 32% are active in classes, 31% encouraging good communication and 19% consider leading in their academic activities. On hard skills it is obtained that 19% find it easy to develop concepts related to their subjects, 12% consider that it is easy to develop mathematical exercises and operations, 32% consider that they have a good capacity for analysis, and 24% indicate that they have analytical thinking, these answers denote that there are shortcomings in the respondents about hard skills.

After the project-based learning pedagogical intervention, the same survey form was applied to determine if there is a differentiation between the initial responses in both the respondents' interest in STEM subjects and soft and hard skills, the following results are shown below.

Table 2 *Results of the end-of-cycle survey form*

Item	Totally agree		I agree		Disagree		Strongly disagree	
	G1	G2	G1	G2	G1	G2	G1	G2
Mathematics								
Math is easy for me	23%	7%	29%	18%	14%	36%	34%	39%
I have improved my grades in math	32%	19%	37%	23%	14%	32%	17%	26%
Sciences								
I understand science subjects well	46%	31%	41%	34%	8%	24%	5%	11%
I do the science work well	40%	22%	31%	23%	12%	26%	17%	29%
I would like to work on something related to science	41%	31%	40%	26%	11%	18%	8%	25%
I consider science subjects important for academic development	52%	37%	39%	31%	6%	17%	3%	15%
Technology								
I like technology	95%	97%	5%	3%	0%	0%	0%	0%
I have the ease to handle technology	83%	80%	14%	14%	3%	6%	0%	0%
I like to constantly handle technology for the development of academic problems	75%	77%	17%	15%	5%	5%	3%	3%
I think technology management is very important for my professional future	94%	94%	5%	6%	1%	0%	0%	0%
I believe that knowing robotics and programming languages contributes to the development of current problems	83%	65%	12%	12%	2%	8%	3%	15%
Engineering								

I like engineering	60%	54%	25%	23%	9%	9%	6%	14%
I like to create and innovate	62%	48%	29%	26%	3%	11%	6%	15%
Soft skills								
I like to actively participate in classes	49%	37%	34%	25%	6%	18%	11%	20%
I like to work in a team	57%	34%	32%	23%	5%	25%	6%	18%
I like to lead my group in academic activities	39%	25%	42%	26%	9%	28%	10%	21%
I like to maintain good communication with my colleagues	57%	34%	38%	31%	3%	26%	2%	9%
Hard skills								
I find it easy to develop concepts related to the subjects	45%	26%	37%	23%	9%	32%	9%	19%
I find it easy to develop mathematical operations and exercises	34%	22%	38%	23%	13%	32%	15%	23%
I believe that I have a good capacity for analysis to solve problems related to the subjects	49%	26%	28%	20%	12%	35%	11%	19%
I consider myself to possess high analytical thinking	42%	23%	35%	22%	9%	32%	14%	23%

The results show that after the application of project-based learning through PhET simulators, greater acceptance by students was encouraged in subjects that usually have a certain level of difficulty and little acceptance, in this sense, it is observed that it went from 2% to 23% of G1 students and 7% of G2, in the same way around the grades in mathematics goes from 19% to 30% in the G1 and 19% in the G2. On the part of the science subjects, there is an improvement of 32% to 46% of G1 students and 31% in the G2 on their ability to understand, from 44% to 52% in the G1 who consider the science subject important for their academic development, while in the G2 37% is obtained. Regarding technology, it is observed that the vast majority of respondents consider that they like it and assume that their knowledge is important for their professional life. On engineering it is observed that it increased from 50% to 60% in G1 students and 54% in G2, regarding their taste for engineering, also from 48% to 61% in G1 and 48% in G2, concerning their taste for innovation, the results show that pedagogical intervention under learning based or projects improves students' perspective on STEM subjects.

Concerning soft skills, it is observed that teamwork there is an increase from 35% to 61% in G1 students and 37% in G2 by this method of work, in their active participation in classes it goes from 32% to 45% in the G1 and 34% in the G2, in the promotion of communication from 31% to 57% in the G1 and 34% in the G2 and finally on leadership in academic activities it goes from 19% to 39% in the G1 and 25% in the G2, these results show that project-based learning encourages the development of soft skills in students, as the G1 shows significant improvements over the G2. De the same way an increase in hard skills is observed, since when comparing results went from 19% to 4 5% in the G1 and 26% in the G2 of students who find it easy to develop concepts related to their subject, went from 12% to 34% in the G1 and 22% in the G2 of students who find it easy perform mathematical operations, there is an increase of 32% to 49% in the G1 and 26% in the G2 of students who consider having a good capacity for analysis and finally from 24% to 42% in the G1 and 23% in the G2 who believe they have analytical thinking.

The results obtained from the Kolmogorov-Smirnov goodness of fit test show a value of 0.00 so the hypothesis that in a parametric sample is rejected and it is accepted that it is a non-parametric sample.

Then it was analyzed if the variable and independent (application of PBL and non-

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application) affects the development of soft and hard skills on an ordinal scale of satisfaction of totally agree to totally disagree, the results obtained from the statistical test are detailed below.

Table 3*results Mann-Whitney U-test*

item	P value
Soft skills	
I like to actively participate in classes	0,003
I like to work in a team	0,001
I like to lead my group in academic activities	0,004
I like to maintain good communication with my colleagues	0,000
Hard skills	
I find it easy to develop concepts related to the subjects	0,001
I find it easy to develop mathematical operations and exercises	0,011
I believe that I have a good capacity for analysis to solve problems related to the subjects	0,001
I consider myself to possess high analytical thinking	0,002

The results obtained from the value in the different questions related to soft and hard skills in the students surveyed present values less than0.05 which indicates a high level of significance in each of the items, that is, there is a significant difference between the means of the group to which the PBL was applied and the group to which it was not, which ratifies that the application of PBL improves hard and soft skills in students.

IV. CONCLUSIONS

The initial results part of the research showed that within the educational institution students have greater difficulty with the subject of mathematics so only 2% mention that mathematics is easy for them and 19% say they have had good grades in the subject. Another subject in which they present some difficulty is those related to science since only 32% understand them well, and 22% say they carry out the work in these subjects properly.

The use of PBL in the careers of Agronomy, Agroindustry, and Veterinary Medicine of the State University of Bolivar achieved an increase in the acceptance of stem subjects in them since there is an increase of 2% to 23% in answers related to the ease in the handling of mathematics, also an increase in the 19% to 32% in students who have improved their grades in the subject of mathematics. In the sciences, it goes from 32% to 46% in the students who understand the subject, in the same way, it goes from 50% to 60% in students who like engineering, as well as innovating and creating.

PBL proves to have statistical significance on the development of hard and soft skills in students since two groups were developed to analyze its incidence, 50% were located within the G1 on which PBL was applied and the other 50% on the G2 applying traditional teaching and learning methods, for which the Mann-Whitney U statistical test was applied under 95% confidence, a value less than 0.05 is obtained, which shows statistical significance, that is, PBL directly affects the development of hard and soft skills in students.

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