FAB-LAB (STEAM) AS A RESOURCE FOR MEANINGFUL LEARNING IN HIGHER EDUCATION

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ABSTRACT

The purpose of this study is to learn about the application of FAB-LAB (STEAM) as a resource for meaningful learning in Higher Education. As it is known, the referred methodology is being implemented since its origins in the United States and is based on inquiry, as a means of obtaining data for the solution of the exposed problem, as well as the consolidation of skills and abilities in the subject "Research Methodology". Thus, in the present research, the need to know in what way the concepts inherent to the research favor the processes of meaningful learning in the Graphic Design Career was proposed. It focused on a quantitative study, the sample is forty-four students between males and females respectively, who were enrolled in the Curricular Unit mentioned above with voluntary decision to participate in the various laboratory practices, as well as the use of inquiry tools to answer the questions posed as part of the study and the project, in general, that is carried out in the ESPOCH. Thus, the results obtained show that with the use of FAB-LAB (STEAM) as a resource for meaningful learning, knowledge is consolidated, as well as collective work, in the same way, students showed acceptance of these activities and the teaching method.

Keywords: STEAM Methodology, STEAM Lab, Meaningful learning, Research Methodology

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RESUMEN

El presente trabajo de investigación tiene como propósito conocer la aplicación de los FAB-LAB (STEAM) como recurso para el aprendizaje significativo en la Educación Superior. Como es sabido la metodología referida está siendo implementada desde sus orígenes en los EEUU tiene su fundamento en la indagación, como medio de obtención de datos para la solución del problema expuesto, así como de la consolidación de las habilidades y destrezas en la asignatura "Metodología de Investigación". Es así como, en la presente investigación se planteó por la necesidad de conocer de qué manera favorecen los procesos de aprendizaje significativo en la Carrera de Diseño Gráfico, los conceptos inherentes a la investigación. Se enfocó en un estudio cuantitativo, la muestra es cuarenta y cuatro estudiantes entre varones y mujeres respectivamente, los que estuvieron matriculados en la Unidad Curricular antes mencionada con decisión voluntaria de participar en las diversas prácticas de laboratorio, así como el uso de las herramientas de indagación para dar respuesta a las interrogantes planteadas como parte del estudio y del proyecto en general que se lleva a cabo en la ESPOCH. Es así como los resultados obtenidos demuestran que con el uso de FAB-LAB (STEAM) como recurso para el aprendizaje significativo los conocimientos son consolidados, así como el trabajo colectivo, de la misma manera los estudiantes mostraron aceptación de estas actividades y del método de enseñanza.

Palabras Clave: Metodología STEAM, Laboratorio STEAM, Aprendizaje significativo, Metodología de investigación

INTRODUCTION

Education is a fundamental aspect of technological progress because from the basis of the study foundation, one can manage to clarify the weaknesses that students have to employ methods that allow turning these weaknesses into strengths, leading to feasible improvements in the teaching processes and therefore of the final results of the study itself. According to Sinchi and Petrona (2018), Ecuador's higher education has transformed in the last decade, in the current constitution the right to it is guaranteed, observing the principle of equal opportunities and permanence through the Organic Law of Higher Education (LOES), so it seeks to implement the application of active methodologies, according to Espinoza-Freire (2021) cited by Guamán & Espinoza (2022) states that active methodologies are characterized by activities aimed at promoting the active and direct participation of the student during the teaching-learning process, giving the role of learning mediator to the teacher, developing research skills, promoting the acquisition of knowledge in an autonomous way, stimulating social relations and communication skills of the learner when working in groups, promoting analysis, reflection and argumentation about what is done and how it is done.

Because the academic innovations developed for this purpose, aim at improving the teaching and learning processes and demonstrating an educational instruction scheme, which is favorable for the greatest number of students. The so-called STEAM model for teaching in Higher Education has received greater acceptance by the academic community in the constructive processes of learning, but also in the schemes where it is intended to prove the existence of meaningful learning. To such effects, STEAM is a method that has enjoyed great acceptance in the teaching of factual sciences "by combining the arts with science, technology and mathematics, engineering and art; which, generates innovation and motivation, besides associating logical thinking with creativity, making science more attractive to students" (Meza & Duarte, 2020, p, 106). In this regard, it is important to note that Guitert and Perez (2013) state that collaborative processes in education are not new., and it is a fact of constant study for the sciences specialized in teaching to adequately enable instructional models, which allow the consolidation and achievement of learning.

At the university level, the STEAM methodology is one of the teaching methods that represent greater comprehensiveness of the concepts, "because it is applied in first world countries for the development of skills and competencies based on the individual capabilities of each student and taking into account the development of multiple intelligences and the role played in educational inclusion by the generation of such spaces" (Asinc & Barzallo, 2019, p. 1507). In Higher Education, the innovations made to ensure improvements to the cognitive processes derive largely from the determination of the needs of the context; therefore, Torp and Sage (1999) state that if any of these tasks pose a new challenge or problem to be solved, techniques of another methodology will be needed to overcome them, such as problem-based learning, which causes the student to encounter a problem without any type of structuring and where he is the protagonist since he identifies and learns from a problem through research and manages to reach a viable solution.

It is known that one of the greatest difficulties that students present at present, especially in subjects and careers of factual specialty is the possibility of consolidating their knowledge, based on their concepts and experiences, which in turn represents an element of learning development with an added value for themselves.

According to Yakman (2008) cited by Ruiz (2017), it can be said that this approach promotes learning to learn in students and learning to transform and intervene in reality from the ability to connect, apply and relate comprehensively to all disciplines of knowledge, as aspects promoted by STEAM education.

In this sense, among the main challenges of the European Union is to increase female participation (identified as one of the biggest gaps) in STEAM (Astegiano *et al*., 2019; Burke & Mattis, 2007; Chiu *et al*., 2018; García-Holgado *et al*., 2020; García-Holgado *et al*., 2019).

In this regard, the pedagogical task is complicated when teaching students with different levels of physical and psychological maturity, since didactic materials and teaching methods are generally designed based on an ideal situation where students do not repeat the curricular content seen in an academic period (Tejada *et al*. 2013). Fonseca *et al*. (2021) assert that:

The lack of diversity is a global problem in different sectors, but it is especially latent in the context of STEM-related fields, from elementary school to university level, and, therefore, in the labor market. Access to the main studies and jobs related to Science, Technology, Engineering, and Mathematics is dominated by the male gender.

In this context, according to (Morgado Bernal, 2012, p. 15), cited by (Arias & Batista, 2021) "learning means acquiring new neural representations of information and establishing functional relationships between them and those already existing in the brain". So, the STEAM methodology is then conceived as an educational model already in higher education that promotes the integration and development of scientific-technical and artistic subjects in a single interdisciplinary framework (Yackman, 2008). The acronym arises in 2008 when Yackman, trying to promote interdisciplinarity, introduces the "A" as the initial of "Arts" in English, which translated into Spanish means "Art", incorporating it into another existing acronym: STEM, which gathers the initials in English of the disciplines Science (S), Technology (T), Engineering (E) and Mathematics (M) (Ruiz, 2017).

According to Ruiz (ob. cit.), what is known today as STEAM implies the learning of these five disciplines that have traditionally been taught separately and in a disjointed manner, and that this methodology proposes their learning in an integrated, articulated manner and under a theoretical as well as a practical approach, as expressed by Yakman (ob. cit.), where he states that the STEAM methodology contributes to the development of an educational model towards the condition of overcoming fragmented bridges in academic subjects that have traditionally been generated in the curricular development in the areas of Science, Technology, Engineering, Arts and Mathematics.

It has usually been conceived even in higher education that students demonstrate their knowledge by employing exams, presentations and text writing, while in the new school it is sought to defend. At present, the traditional teaching model, characterized by a high proportion of mechanical learning, is pursued, although, by intuition, procedures are used to achieve learning based on understanding (Arroyo, 1992). In this order, educational innovation has granted the flexibility of educational curricula and instructional methods, therefore one of the advantages of the STEAM methodology is the possibility of working with complex problems from different disciplines giving creative and innovative solutions with the use of possible technologies (Sevilla & Solano, 2020), the primary advantage of the STEAM model is the individual development of skills and abilities regardless of the context, however at present the so-called STEAM laboratories or FAB-LAB STEAM have arisen.

In higher education it is often possible to link learning processes with the theory of constructivism proposed by Vygotsky (1980) who observed how people learn based on already acquired knowledge, developing the concept of scaffolding. Thus, it can be said that the STEAM methodology, being based on the constructivist approach to learning, promotes the construction of knowledge in a meaningful and collective way among students and teachers. Even though constructivism is a model in which old and new concepts are articulated and give rise to the consolidation of learning in the learner, it is also feasible to define that new knowledge does not occur if it does not have real meaning for the subjects or the subject, in this case, described as the apprentice.

In this order, the concept of meaningful learning of Ausubel *et al*. (1998, p. 20) arises: "The principles of learning apply to all classroom practices such as grouping, marking, didactic materials and methods", so it is advisable to take into account the different problems of learning that occupy psychology and that should be considered by the teacher. Thus, the different problems that can occur in the classroom, when learning, are those of which educational psychology is concerned (Ausubel *et al*., 1998), such as a) the aspects of the learning process that may affect the acquisition and retention of knowledge, b) the development of learning and problem-solving skills, c) the cognitive and personality characteristics of the student, d) the interpersonal and social aspects of the context, environment or learning scenario that interfere in the learning of a given subject, subject or area, e) the interest or motivation to learn or assimilate, and f) the ways of organizing and presenting materials.

Thus, Ecuador, as a multicultural country, needs an education that responds to diversity as part of the human condition, that acts as a factor of socialization and develops thinking for the achievement of meaningful learning to achieve this objective, a strategy consisting of cooperative learning is proposed (San Felipe Neri, 2019). Thus, meaningful learning is today and has long been commonplace, that label that teachers, pedagogues, teaching organizers and curriculum planners use to express what students are supposed to achieve (Rodríguez *et al*., 2010).

Meaningful learning implies questioning and requires the personal involvement of the learner, i.e., a reflective attitude towards the process itself and the content being learned, so that the learner asks what he/she wants to learn, why and what is the purpose of learning it meaningfully. Thus, a new contribution arises, which is its critical nature (Moreira, 2000 b, 2005, 2010). For Santillán *et al*. (2019), the representative elements of STEAM education are intertwined with the possibility of establishing concepts inherent to meaningful learning based on: 1) The interdisciplinary approach, 2) The social skills to solve problems, 3) The creative strategies, 4) The digital opportunities and challenges, 5) The integral capabilities of the human team, which are the theoretical elements used in this research for the analysis of the two STEAM learning projects applied by the author in the university educational context:

According to Santillán *et al*. (2020):

STEAM Education allows providing answers and solutions to real-life problems through the development of learning projects, which intervene in reality to transform it while promoting meaningful and critical learning in students through the search for creative and comprehensive solutions. It is important to note that this aspect is complemented with what was discussed in previous paragraphs about the interdisciplinary model as one of the theories that support the STEAM methodology (p. 476)

In this way, ESPOCH (2022) asserts:
A fundamental transformation of education and training is needed to address the new competencies and skills required to adequately prepare students for life in the future society. To increase the range of innovative products that reflect the needs of society, it is necessary to attract an adequate number of young people to STEAM fields and to link research careers with the changing needs of the labor market. In this context, EPOCH through the faculty of computer science and electronics has been carrying out several undergraduate degree projects and graduate theses on the topic of 3d modeling, animation and simulation, without the students or master students having a specialized laboratory. The projects are usually carried out by the students themselves and make use of facilities, laboratories and workshops external to the faculty where the costs of products are high. (p.7)

Within the Faculty of Computer Science and Electronics of the Escuela Superior Politécnica de Chimborazo, the guiding principles of the STEAM model and the practices that derive from its implementation have been implemented as a novel teaching method for the achievement of individual and collective academic goals, Because it has been evidenced that in subjects with a higher level of difficulty and the contents of other theoretical subjects there are also cognitive gaps in the students, as these changes occur, it becomes necessary to generate specific pedagogical configurations that allow the development of prepared individuals (Leong, 2017).

Thus, it has been proposed according to the conception of the projects within which it has been implemented the use as a resource of a STEAM Laboratory formalized according to ESPOCH (Op. Cit.) from its conception (design, location, operation logistics) to its materialization. However, it is necessary to take a step forward and establish new lines of research and services to expand the scope and diversification of the STEAM Thinking Lab. From this point of view, the evolution of the Thinking-Lab towards a FAB LAB will allow increasing the know-how of the Faculty of Computer Science and Electronics, focusing on a product level. The software products to be developed will be supported by the hardware, specifically by a specialized laboratory that will be able to provide services such as:

- 3D Milling
- 3D Printing
- 3D Modeling
- Prototype preparation
- Others

So, by analyzing the effects that can be produced by laboratory practices and designs that are desired to formalize through the creation of team productions, it is estimated that progress can be verifiable and measurable through the incorporation of a STEAM Thinking Lab, in the processes of higher education in today's University. Therefore, the objective of this research is to know the application of the FAB-LAB (STEAM) as a resource for meaningful learning in Higher Education, in the context of students studying the specialty of Graphic Design at the Faculty of Computer Science and Electronics of the Superior School of Chimborazo in the Province of Chimborazo, Ecuador.

MATERIALS AND METHODS

Design

The present study was defined as a quantitative type of research, practices were structured to verify in the period from October 2021 (test) to March 2022 (post-test), the progress of students in applying concepts inherent to the subject of Research Methodology in the Graphic Design Career of the Escuela Superior Politécnica de Chimborazo, Province of Chimborazo in Ecuador.

Procedure

For the development of this study, emphasis was placed on the fulfillment of a series of stages such as the following:

1. Delimitation of the scope of the investigation, expressly to what extent it is desired to investigate.
2. Consideration of the variables to be studied
3. Definition and selection of the context and population sample
4. Structuring of the scheme to be followed to apply the diagnosis based on the academic planning of the teachers involved in the project that includes these practices of Fab. STEAM with students from different careers including Graphic Design, as mentioned above.

Thus, for the development of the research presented, it was possible to make a previous selection of the subjects that make academic life within the Escuela Superior Politécnica de Chimborazo, specifically in the Faculty of Computer Science and Electronics, students of the Graphic Design Career, who voluntarily decided to participate in the present study, likewise it was determined with the use of the deductive method and presented the results through descriptive statistics, the aspects related to the studied variable.

Population sample

The sample was selected based on the criteria of students enrolled in the Graphic Design Career of the Escuela Superior de Chimborazo within the Faculty of Informatics and Electronics, those subjects enrolled in the subject "Research Methodology", the period October 2021 - March 2022 have been selected so that the same has followed a purposive sampling. For this purpose, the members of a particular course were taken on which a series of practices defined in the context of the implementation of the STEAM laboratory within the institution were applied to verify the positive and demonstrable effects through research, of meaningful learning of the students.

Table 1. Enrollment of Graphic Design students taking Research Methodology.

CAREER	LEVEL	PARALLEL A		TOTAL
		Male	Female	
Graphic Design	Seventh	31	13	44

Source: Santillán (2022)

As can be seen, the enrollment of male students is higher than that of female students.

DISCUSSION

The following are the results and discussion inherent to the observations made during four class sessions with Graphic Design students taking the subject "Research Methodology", who have been surveyed about the application of these tools related to the implementation of the STEAM laboratory for the development of elements concerning Meaningful Learning at the corresponding level.

1. Two lesson plans were structured based on the traditional classroom teaching scheme with the contents of the course syllabus, and a second lesson plan was structured with STEAM activities.
2. At the end of both, an instrument was applied to the basic criteria: acceptance of teaching techniques, need to change the method of instruction by the teacher, activities that promote the achievement of learning objectives, as well as teacher motivation through the implementation of the STEAM Laboratory for the subject Research Methodology.

Table 2. Acceptance of Teaching Techniques

Instrument Measurement Scale	Pretest	Postest	Pretest	Postest
	Absolute Fr.	Absolute Fr.	Absolute % Fr.	Absolute % Fr.
Strongly disagree	0	0	0	0
Disagreement	20	0	45	0
Neither agree nor disagree	10	6	23	14
Agreed	10	30	23	68
Very much in agreement	4	8	9	18

Source: Santillán (2022)

The results of Table 2 show that students are in favor of the implementation of the STEAM lab for meaningful learning since 68% of the respondents stated that they are in favor of the implementation of this tool as a resource for individual and collective teaching.

Table 3. Activities carried out with the work objectives.

Instrument Measurement Scale	Pretest	Postest	Pretest	Postest
	Absolute Fr.	Absolute Fr.	Absolute % Fr.	Absolute % Fr.
Strongly disagree	0	0	0	0
Disagreement	7	4	16	9
Neither agree nor disagree	23	7	52	16
Agreed	8	9	18	20
Very much in agreement	6	24	14	55

Source: Santillán (2022)

Following the instructional objectives set out in the use of the STEAM laboratory as a technological and educational work tool for students in the specialty of Graphic Design, specifically in the subject "Research Methodology", what we have in itself from the responses of the students is the favorable appreciation of the activities developed as part of the evaluations and formative assignments, obtaining 55% acceptance of the implementation of the STEAM laboratory.

Table 4. Motivation for students from the role of the teacher who implements the teaching method.

Instrument Measurement Scale	Pretest	Postest	Pretest	Postest
	Absolute Fr.	Absolute Fr.	Absolute % Fr.	Absolute % Fr.
Strongly disagree	1	0	2	0
Disagreement	1	5	2	11
Neither agree nor disagree	28	6	64	14
Agreed	11	14	25	32
Very much in agreement	3	19	7	43

Source: Santillán (2022)

Regarding the motivational aspect, a valuable element to consider in the processes of consolidation of meaningful learning, 43% of the students affirm that they feel interested in participating in the collaborative activities that are carried out in the STEAM Laboratory as part of the practices for the "Research Methodology" course, thus approving the mechanisms used by the teacher as a mediator of the learning processes. Representing 43% of the acceptance of the tasks performed that motivate the participants of the educational event.

Table 5. Perceived improvement of academic goals and their relationship to cooperative activities as a result of the teaching method employed.

Instrument Measurement Scale	Pretest Absolute Fr.	Posttest Absolute Fr.	Pretest Absolute % Fr.	Posttest Absolute % Fr.
Strongly disagree	0	0	0	0
Disagreement	7	0	16	0
Neither agree nor disagree	21	1	48	2
Agreed	7	33	16	75
Very much in agreement	9	10	20	23

Source: Santillán (2020)

According to the results obtained after applying the two phases developed as part of the present study, the pretest and posttest, the students consulted stated "In agreement" with 75% of this evaluation scale, the improvement of the conditions for the achievement of academic goals.

Table 6. Preference for activities using the subject's STEAM Lab to consolidate learning.

Instrument Measurement Scale	Pretest Absolute Fr.	Posttest Absolute Fr.	Pretest Absolute % Fr.	Posttest Absolute % Fr.
Strongly disagree	0	0	0	0
Disagreement	5	0	11	0
Neither agree nor disagree	7	12	16	27
Agreed	20	20	45	45
Very much in agreement	12	12	27	27

Source: Santillán (2022)

45% of the "Agree" scale shows the satisfactory evaluation of the students in terms of the achievement of significant learning by the participants, indicating their preference for the STEAM Lab activities instead of the traditional classroom activities.

Table 7. Acceptance of the teaching model adopted by the teacher

Instrument Measurement Scale	Pretest Absolute Fr.	Posttest Absolute Fr.	Pretest Absolute % Fr.	Posttest Absolute % Fr.
Strongly disagree	0	0	0	0
Disagreement	7	2	16	5
Neither agree nor disagree	28	7	64	16
Agreed	8	9	18	20
Very much in agreement	1	26	2	59

Source: Santillán (2022)

About the method used by the teacher and the student's evaluation of it, 59% of the students consulted stated that they "strongly agree" with the educational strategies implemented by the teachers, especially with the teacher of the subject "Research Methodology" to promote better context conditions for the achievement of meaningful learning, this concerning the activities proposed by the teacher.

From the exposed results, the criteria related to the establishment of improvements in the conditions for the students to learn in a meaningful way and to reach the instructional objectives in a better way have been evaluated, being then the expected results widely favored by the planning of the knowledge with the support of the STEAM laboratory, since it has been established as a teaching resource that promotes meaningful learning from the foundations of knowledge, meaningful learning is the central construct of Ausubel's original conception, which expresses the mechanism by which meanings are attributed in formal classroom contexts and which assumes certain conditions and requirements for its achievement. It supposes the constructive integration of thinking, doing and feeling, which constitutes the fundamental axis of human aggrandizement. It is a triadic relationship or interaction between teacher, learner and educational materials of the curriculum, in which the responsibilities corresponding to each of the protagonists of the educational event are delimited. In this sense, the 59% favorable evaluation made by the students of the method used by the teachers in terms of the acceptance of the teaching technique and the strengths that these represent for the development of skills and abilities in the subject "Research Methodology" as well as the consolidation of learning is of great relevance for the implementation of STEAM laboratories in the Polytechnic School of Chimborazo, in the province of Chimborazo, Ecuador. As referred by D`Souza and Rodrigues (2015) who indicated that in various researches in Cognitive Psychology have revealed that students reach a higher degree of information processing through metacognition and active learning, even establishing that this type of learning surpasses in many ways the expository methods. It is even suggested that methods based on active learning increase students' performance, motivation and retention capacity. Likewise, 55% of the students stated that in the resolution of the approaches made in the subject and the achievement of the learning objectives the implementation of the STEAM Laboratory represents a favorable resource, for this Sanchez (2018) when referring to the STEAM methodology as an element for structured learning that encompasses several disciplines but does not enhance any in particular but rather gives importance to the transfer of content between subjects, which favors meaningful learning.

CONCLUSIONS

At the end of the research, it is evident that the general objective of the research work was fulfilled, during the diagnostic process, the students stated that the activities developed during the post-test stage in which the STEAM laboratory was used for the development of the activities proposed by the teacher were better accepted by the participants of the subject "Research Methodology", which in turn allowed conclusions to be drawn from the modification of the forms of interaction among themselves as part of the sample, allowing each student to have experiences of inquiry in the conception of the methods of obtaining the answers to the approaches made by the teacher of the subject on the topics to investigate, so that the results regarding the perception that students have of the training and evaluation strategies give the STEAM method and the laboratory designed at ESPOCH a favorable criterion for future activities in other curricular units, in which it is necessary to favor the conditions to promote meaningful learning as an element of projection of the new professionals, with an integral character in the different subjects they take.

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