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ORIGINAL

Planning, design, and implementation of STEAM projects through the flipped classroom methodology for high school students in Ecuador.

Planificación, diseño y ejecución de los proyectos STEAM mediante la metodología de la clase inversa para estudiantes bachilleres en Ecuador

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ABSTRACT

The STEAM project encompasses several areas of study: Science, Technology, Engineering, Arts, and Mathematics, reflecting its interdisciplinary nature that supports the comprehensive education of students in the Unified General Baccalaureate. Therefore, it is necessary to identify the critical and success factors related to its design, planning, and implementation in the case of the Unidad Educativa Fiscal 10 de Agosto in the city of Quito, during the 2024-2025 academic period. The research adopted a quantitative approach with a non-experimental, cross-sectional design, in which surveys were applied to teachers from the afternoon session and students from the Unified General Baccalaureate to characterize their perceptions regarding their knowledge, the procedures they manage, and the management of STEAM projects. The results obtained led to the design of a proposal based on the flipped classroom method, mediated by the use of technology; interactive activities that students can carry out autonomously and outside the classroom, fostering effective teacher-student feedback as a complement to the teaching-learning process, the development of individual and collaborative skills, and the strengthening of meaningful learning. This interactive didactic guide is designed in Google Sites, is easy to use for both teachers and students, facilitates the design, planning, and execution of STEAM projects, and confirmed the effectiveness of the flipped classroom as a viable and favorable alternative for such purposes.

Keywords: Steam; Interdisciplinarity; Flipped Classroom; Meaningful Learning; Collaborative Skills.

RESUMEN

El proyecto STEAM abarca varias áreas de estudio: Ciencia, Tecnología, Ingeniería, Arte y Matemática, entendiéndose su interdisciplinariedad que favorece la formación integral de los estudiantes del Bachillerato General Unificado, por lo que es necesario identificar los factores críticos y de éxito en torno a su diseño, planificación y ejecución en el caso de la Unidad Educativa Fiscal 10 de Agosto de la ciudad de Quito, en el período 2024 - 2025. La investigación asumió un enfoque cuantitativo, con un diseño no experimental de corte transversal, donde se aplicaron encuestas a docentes de la jornada vespertina y a estudiantes del Bachillerato General Unificado para la caracterización de sus percepciones en torno al conocimiento que poseen, procedimientos que manejan y gestión de los proyectos STEAM. Los resultados obtenidos, permitieron el diseño de una propuesta basada en el método de la clase inversa, mediada con el uso de la tecnología;

actividades interactivas que el estudiante pueda realizar de forma autónoma y fuera del salón de clases, que favorecen la retroalimentación efectiva docente – estudiante, como complementariedad al proceso de enseñanza aprendizaje, al desarrollo de habilidades individuales y colaborativas y al fortalecimiento del aprendizaje significativo. Esta guía didáctica interactiva está diseñada en Google sites, es de fácil manejo para docentes y estudiantes, posibilita el diseño, planificación y ejecución de los proyectos STEAM, además permitió corroborar la eficacia de la clase inversa como alternativa viable y favorable para tales propósitos.

Palabras clave: STEAM; Interdisciplinariedad; Clase Inversa; Aprendizaje Significativo; Habilidades Colaborativas.

INTRODUCTION

"It is tough to maintain scientific curiosity in a rigid educational system. The spirit of discovery and creative thinking is lost in the school routine" (Albert Einstein). This is constructive criticism that invites us to reconsider the training methodologies used today, which should promote and maintain the ability to learn by involving innovative and dynamic strategies that, in addition to respecting the naturalness of unlimited discovery, can also respond to a society that is advancing at a rapid pace, with demands on the preparation of present and future generations to function in different fields without difficulty.[1,2,3,4,5,6]

Based on the above thinking and in conjunction with other issues or demands from the Ministry of Education, the planning, design, and implementation of STEAM projects using the flipped classroom methodology for students in the General Unified Baccalaureate program in the subject of Biology at the 10 de Agosto Educational Unit in the 2024-2025 school year is proposed.[7,8,9]

This approach is in line with the implementation of the STEAM project and the flipped classroom, as both aspects, taken together, generate an interdisciplinary educational complementarity based on innovation in a different way of learning that guides students to be the protagonists of their knowledge, to be autonomous, committed, motivated, and critical thinkers, adapting to the environmental reality and competencies of today's society.

On the other hand, mention is made of the teaching staff's ability to develop and share this type of training with other colleagues, which, beyond considering biology content, can be adapted to other disciplines, as flexibility is one of the characteristics of this proposal. Furthermore, this proposal can be seen through the tools provided by Google Sites and Google Classroom, which are spaces that have the resources, links, and descriptions that give teachers innovative ideas for modifying their classes so that they are taught with an awareness of the changing roles (teacher-student) and so that students can develop skills among their peers.[10,11,12,13,14]

In recent years, there has been an urgent need to transform the education system. As indicated by the United Nations Educational, Scientific and Cultural Organization[1], we must promote the advancement of an equitable society that can address and solve various forms of inequality and the intriguing future of work. However, such a transformation is not possible without the validation and fulfillment of teachers, who must reflect on their teaching practices and be committed to involving students and communities in their social reality and the problems of their environment, through actions that are learned and taught in educational institutions, which assume a role as facilitators and guides for students.[15,16,17,18,19]

In response to this situation and these requirements, the Ecuadorian Ministry of Education[2], through a "Guide to the implementation of the STEAM methodology" (an acronym for Science, Technology, Engineering, Arts, and Mathematics) proposes implementing an interdisciplinary approach involving five disciplines—science, technology, mathematics, art, and engineering—as an alternative that allows for modifying traditional learning environments and providing spaces for analysis and meaningful learning based on novelty in a real-world context.[20,21,22,23,24]

Likewise, to continue the development of meaningful training, MINEDUC[2], through its report on the results of the "Evaluation of Educational Innovation Projects and Practices" issued on April 12, 2022, announced the participation of the three leading institutions that won awards for the development of innovative projects. This means that projects are being implemented that involve teachers and students in finding striking solutions to problems in their context. However, only twelve institutions participated, indicating a need to train, motivate, and encourage teachers to develop problem-solving projects.[25,26,27,28,29,30]

On the other hand, through its Pasa la Voz program, MINEDUC[3] shares a series of active methodologies, an initiative that originated during the pandemic, when face-to-face classes became virtual classes, requiring the teacher-student role to adapt to new learning environments and strengthening autonomous learning among students. Furthermore, with the return to face-to-face learning, the use of digital educational methodologies has emerged and is here to stay. This is the case with the flipped classroom methodology, which changes the dynamics between teacher and student without losing the meaning of education, where students can arrive with prior information and experience.[31,32,33,34,35]

Therefore, based on the above considerations, this study aims to ensure that the design, planning, and implementation of STEAM projects, applying the flipped classroom methodology, complement the innovation sought by educational institutions to work more dynamically, which in turn serves as a tool to be developed in an assisted or individual manner, working in the classroom with the teacher and outside the classroom, individually.[36,37]

Context

When proposing an interactive teaching guide for the application of the STEAM project using the flipped classroom, it is essential to mention that a large number of teachers do not use active methodologies, which makes classes monotonous and boring. This means that the tasks and activities carried out by students are only informative and documentary in nature, which does not contribute to the construction of meaningful learning to a large extent, nor does it lead to actual collaborative work, let alone interdisciplinary work.[38,39,40]

To change this reality, theoretical biology classes must be set aside and transformed into proactive classes during the teaching-learning process, which in turn can generate meaningful, critical, and reflective learning in each Performance Standard (PS) developed in the classroom using the STEAM Project and applying the flipped classroom methodology, which can have a significant impact on educational transformation, making it interdisciplinary and innovative.

This methodology facilitates the development of the STEAM project more effectively, as activities are planned to be carried out synchronously in the classroom or virtual classes, provided conditions allow, and asynchronously when face-to-face classes are not possible or students cannot connect to virtual courses. In this sense, these activities will be posted online so that students can continue their learning without interruption.[41,42,43]

When developing the STEAM[3] approach (hereinafter referred to as the STEAM Project), teachers sometimes know the meaning of the acronym but do not know how to implement it properly, especially when it comes to generating interdisciplinary projects that involve all areas and are of institutional interest and innovation from the learning process in different fields.

In some cases, the STEAM project is only written in the teacher's lesson plans or the students' notebooks and is not fully implemented to present an adequate final product where the five disciplines that are interacting and are part of the meaningful learning sought in upper secondary education can be visualized.[44,45,46,47]

In addition, the STEAM project must be developed using a methodology that enables students to interact, plan, and execute the DCDs and disciplines or areas of knowledge involved. That is why the flipped classroom method is proposed to develop step by step, synchronously and asynchronously, with students in person or virtually.

Problem statement

How can the STEAM Project be planned, designed, and implemented using the Flipped Classroom method for students in the Unified General Baccalaureate program in the Biology course at the 10 de Agosto Public School during the 2024-2025 school year?

General objective

Propose a plan, design, and implementation of the STEAM project using the flipped classroom methodology for students in the General Baccalaureate program in the subject of Biology at the Unidad Educativa Fiscal 10 de Agosto during the 2024-2025 school year.

Specific

1) Theoretically support the significance of the STEAM project and how the flipped classroom can help in the practical process.
2) Investigate the perceptions and experiences of teachers and students regarding the application of the STEAM project and the flipped classroom in the subject of Biology.
3) Design an interactive guide that serves as methodological guidance for the proper development of STEAM projects based on the use of the flipped classroom in the Biology class.
4) Validate the proposal through expert criteria for future implementation and share the results of the activities implemented in the classroom with respect to the established proposal.

State of the art

Núñez[4] reports on the "STEAM methodology as a teaching strategy for general electronics in first-year technical high school students at the Carlos Cisneros Educational Unit," which focuses on the development of effective learning strategies, such as constant practice, problem solving, and active participation in the classroom. Furthermore, this research analysis concludes that the STEAM methodology allows for the construction of comprehensive, complex, and interdisciplinary knowledge through active methods that seek to promote the development of critical, creative, reflective, and logical thinking and, above all, the development of cognitive processes.

In the research project by Rodríguez et al.[5], the main objective was to demonstrate how educational mobile applications were an excellent tool for teaching, using the STEAM methodology. In this regard, to discover the importance of this tool, they applied the technological component and qualitative performance method, which allowed them to conclude that students had a positive impact with the use of this new tool and that new forms of teaching and learning should now be adopted, as they have become a necessity to awaken students' interest in learning.

Villavicencio[6], in his study on "Application of the STEAM methodology in the teaching-learning process of students," began by defining the STEAM methodology and its application in the teaching-learning process to diagnose the implementation of the STEAM methodology through surveys of high school students. In addition, it concludes that applying the STEAM methodology in educational institutions significantly contributes to education by developing various skills and abilities. Therefore, it recommends working on interdisciplinary projects, as they encourage innovation and provide practical opportunities for students.

From Saiz's[7] perspective, increasing student motivation is a necessity, which is why he proposes a methodology based on STEAM intervention, as it will bring them closer to the reality of the world of work in the scientific field and is based on inquiry-based learning, in which they will build their knowledge. Finally, he concludes that it is necessary to select the appropriate tools in advance to serve as resources that allow students to learn independently and individually.

Rodríguez[8] mentions in his research that incorporating STEAM models is essential for the development of skills and abilities. The results obtained from the application of the STEAM system proved to be favorable in the development of creativity, making children more active and creative, with a better predisposition to solve problems in a concrete and collaborative way. It can therefore be concluded that the system is an interesting learning tool that can be applied in whole or in part, depending on the desired scope and the creative abilities of teachers to generate activities that enhance children's skills and promote tolerant coexistence.

The contributions made in the various research projects mention that the planning and design of STEAM projects are of great importance in the development of conceptualization in the classroom. While it is true that STEAM covers several areas, allowing teachers to work on interdisciplinary projects and use active methods such as the flipped classroom, so that they can opt for new ways of teaching in line with the demands of the 21st century, it should be emphasized that today we have technology on our side, which should be taken advantage of through the application of artificial intelligence that students can actively use with the guidance of the teacher.

STEAM projects enable us to maximize our learning potential, which is why they can help develop various skills in students, including creativity, critical thinking, problem-solving, leadership, communication, and collaboration. These profiles meet the expectations of today's society, promoting the development of students' skills.

Definition of a STEAM project

According to MINEDUC[3], the acronym STEAM stands for Science, Technology, Engineering, and Mathematics, and defines it as an interdisciplinary approach to learning; an initiative that seeks to develop and integrate all areas of the curriculum, while promoting collaboration, creativity, problem solving, and the development of systemic thinking in students. Despite these clarifications, many educational institutions do not clarify the concept of STEAM.[9]

The STEAM project (as it is often called in educational institutions) seeks to apply knowledge from various areas through practical activities and specific challenges. These projects allow students to work in teams, fostering critical thinking and innovation. In addition, they are based on methodologies such as project-based learning, cooperative learning, and the flipped classroom, which will be used in this research to develop asynchronous activities with students and ensure the proper development of the STEAM project.[10]

A clear example of the STEAM project is the design, architecture, and construction of a sundial, allowing students to apply concepts from physics, mathematics, science, and art to create a device that measures time using sunlight.[3] For his part, Castell[11] points out that critical thinking and motivation are fostered in students when learning biology topics, such as the creation of 3D invertebrates, which has led students to analyze and evaluate their work.

In many cases, students believe that education in a subject is individualized and unrelated to other subjects, much less that the knowledge gained in each subject applies to everyday life. This is the meaning of the STEAM Project, which will henceforth be referred to as such in this research, because teachers and students in the vast majority of educational institutions know it this way, since in some cases it has even been called a methodology, some researchers have called it an approach, and others simply STEAM education.

Teachers are not just transmitters of knowledge; they are trainers, researchers, motivators, and today, they must be guides for life. Which is why the STEAM project is so important, as it involves five areas of knowledge, in addition to forming diverse work teams and assigning a specific role to each student as they develop the project in an integrated manner, allowing them to move toward cross-curricular learning and skills, since different disciplines are combined, encompassing common projects that contribute to strengthening meaningful learning and collaborative work among students.

The development of the STEAM Project is significant because, in a short time, educational institutions in the country have been gaining ground, interest, and approval for its implementation, or are in the process of doing so, considering also, as educators, that education should be comprehensive and interdisciplinary, in that it does not focus on a single subject, but integrates several areas of knowledge. Despite this, there is little research on how to apply the STEAM project sequence in educational institutions.

Definition of flipped classroom

The flipped classroom methodology allows content to be delivered outside the classroom. Williner[12] suggests that this can be achieved through videos, readings, or other resources like Canva or Google Drive, allowing students to collaborate before or during virtual classes. In face-to-face courses, time is spent on practical activities, discussions, problem-solving, and clarifying doubts, with the guidance of the teacher.

The flipped classroom is an alternative methodology that leads to the efficient use of time spent in face-to-face classes, reintegrates the active role of each student, and creates a more effective learning environment.[13] In this sense, this methodology transfers specific tasks outside the classroom so that students can use their time at home to review each task, making classes more participatory and dynamic for students.

The flipped classroom methodology has benefits for both students and teachers. In the case of students, it encourages collaborative work, allows them to study different topics at their own pace, makes them participants in their learning, helps them acquire skills such as creativity and analytical ability, allows them to make the most of their time at home, and makes them more participatory in class. On the other hand, among the benefits for teachers is that they interact with and clarify students' doubts, act as guides and facilitators of learning, and monitor, accompany, and distinguish each student's progress and performance.[13]

When using this methodology, multiple technological tools must be used to ensure effective and efficient learning among students.[14] The work carried out by teachers is vital because they are responsible for preparing the material to be used, such as videos prepared and recorded by the teachers themselves, or videos compiled from YouTube or other websites or platforms, which students can access from home and use to acquire knowledge that they can then present in class. It is at this point that the teacher becomes a guide and is responsible for clarifying any doubts, questions, or observations that the student may have.

For their part, Bergman et al.[15] recommend that teachers apply seven basic rules to move forward with the flipped classroom model:

Introduce students to the model. Define each of the student's tasks precisely. Please review each of the videos and documents directly with them to involve them in the learning process; ask clear and interesting questions. This will allow you to check that students are constructing meaningful learning. Prepare the classroom learning environment. In class, you can work on problem-solving activities or discussions.

Manage students' time and workloads. When they are unable to attend virtual classes, they will have to establish their own activities. Collaboration and support among students. This reflects the collaborative work among students to carry out the different activities in face-to-face or virtual classes. Develop an assessment method. For example, use rubrics that allow students to self-assess and co-assess their peers.

On the other hand, Blog Campuseducacion.com[16] shares five steps to implement the flipped classroom methodology through its portal, which aligns with our research and is summarized below:

1. Scheduling: refers to recording the topics to be studied together with the objectives.
2. Multimedia preparation: selecting multimedia material.
3. Sequencing of time outside the classroom: structuring how to give continuity to the content, being synchronous and asynchronous.
4. Classroom session design: implementing a physical or digital resource that reflects the activities to be carried out.
5. Distribution of the rest of the time: alternating synchronous and asynchronous work times.

Based on the above, the flipped classroom is considered a teaching methodology that benefits both students and teachers and, together with the use of multiple digital tools, allows for good results in student learning and performance. For this reason, teachers must be committed to guiding students through observation, feedback, and constant evaluation, thus giving students a leading role in their learning process. Above all, it is very important to carry out each of the steps to implement this methodology in order to obtain more effective results that benefit students.

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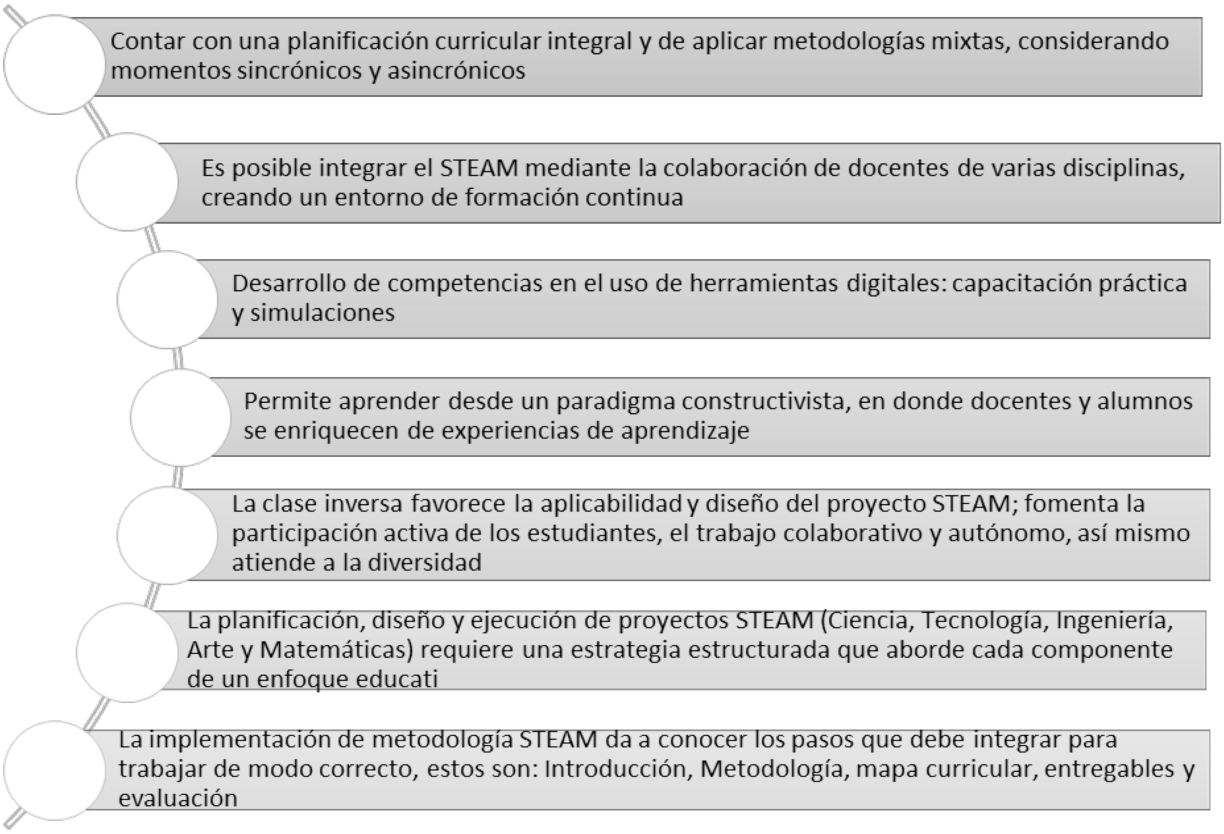


Figure 1. Teachers' perspectives on the STEAM project in biology

The figure presents a clear and coherent path for the implementation of STEAM projects in education, highlighting essential components such as comprehensive curriculum planning, interdisciplinary teaching, the development of digital skills, and the constructivist paradigm. Among these elements, the flipped classroom stands out as a methodological resource that promotes active, autonomous, and collaborative learning, which are fundamental conditions for the success of STEAM projects.

The flipped classroom is crucial because it allows students to arrive in the classroom with a prior knowledge base, freeing up time in face-to-face sessions for practical, experimental, and interdisciplinary activities, which are characteristic of the STEAM approach. In addition, this model caters to diverse learning rhythms and styles, facilitating inclusion and personalization in the educational process.

Likewise, the figure indicates that the design and implementation of STEAM projects cannot be improvised: it requires a clear structure that integrates the introduction, methodology, curriculum map, deliverables, and evaluation. In this sense, the flipped classroom favors this Planning by distributing synchronous and asynchronous moments in a balanced way, optimizing the time and resources of both the teacher and the student.

In conclusion, the figure shows that the flipped classroom is not just a complementary tool, but a strategic methodological resource for ensuring the effectiveness of STEAM projects by promoting a more participatory and reflective learning culture that is connected to the challenges of the 21st century.

METHOD

This study uses a quantitative research approach, as it "reflects the need to measure and estimate the magnitude of research phenomena or problems".[17] In this case, we analyze the application of the STEAM project together with the flipped classroom methodology in BGU students in the Biology course, considering the context and reality of the educational institution. In addition, it aligns with the objective of the study, which is based on a problem identified by an academic group. The data generated by the group is then integrated and discussed from a quantitative perspective.

The study is correlational. According to Díaz et al.[18], correlational research "attempts to discover whether two or more concepts or properties of objects are associated, how they are associated, and to what degree or magnitude they are associated". Given this, the present research aims to investigate the interrelationship between the variables Planning, design, and execution of STEAM projects, and the flipped classroom methodology in general high school students, proposing a guide for the implementation of innovative training.

The research detailed here is field research because it involves collecting data directly in the environment, which is the 10 de Agosto Public School, through surveys of teachers and students. This allows for the study of teachers' knowledge of the STEAM project with the application of the flipped classroom and, in turn, the results achieved by the students, so that real information can be obtained based on the observation of the participants. The data collection will therefore serve to propose a proposal according to Bergmann et al.[19].

Among the contributions made to the STEAM project, active methodologies such as the flipped classroom were used, taking advantage of technological advantages, as these are fundamental for the development of modern and practical education. These strategies not only improve the understanding and application of interdisciplinary knowledge but also prepare students to face the challenges of the future creatively and innovatively.

It is also classified as a bibliographic modality because it is based on the review and analysis of existing literature, such as scientific journals or master's theses, to theoretically ground the research project to be carried out and relate it to the interpretation of the results obtained,[19] by reviewing the literature that has allowed the theoretical research framework to be formed from scientific articles and relevant works from the last five years, for the most part.

The study is non-experimental because no independent variables are deliberately manipulated. Instead, the effect of the flipped classroom methodology, meaningful learning, active participation, and collaborative work within the STEAM project in its natural environment is observed and analyzed without the intervention of the researcher.[20] It should be noted that, due to the short time frame, the proposal is only being presented and not implemented. However, it can be developed over time to observe any changes that may arise from the proposal.

The research design is non-experimental and cross-sectional, as data is collected at a single point in time to analyze the relationship between the variables mentioned.[17] This enables the collection and analysis of data to determine the relevance and importance of addressing the problem posed in STEAM project management through the flipped classroom methodology.

This research study is being carried out at the Unidad Educativa Fiscal 10 de Agosto located in the city of Quito, San Sebastián parish, during the 2024–2025 school year, at the General Unified Baccalaureate (BGU) level, where the survey will be administered, information will be collected, and the results of the data obtained will be analyzed. Thus, the population is defined as a total set of events that are closely related to a series of specifications.[17]

The population of this research project consists of 140 BGU students enrolled in the Biology course and 23 afternoon teachers who will help address general concerns about the development of the STEAM project using the flipped classroom method. Next, data will be collected to enable the research to be carried out, and a certain number of students will be selected to whom the analysis will be applied in order to work with the sample.

The sample consists of two study groups, namely teachers and students. On the one hand, the sample of teachers is finite, as the subjects were chosen based on the characteristics required to carry out the study. As for the students, they are considered a group belonging to BGU. Therefore, both groups are considered viable to work as a universal population, as it is feasible for data collection.

Surveys are widely used in quantitative research and are defined as "a technique that consists of obtaining information directly from people who are related to the object of study".[21] In this survey, a questionnaire with closed questions is used as a tool for data collection, which facilitates the quantification of the different responses.

The instrument to be used in the survey is the questionnaire because it consists of a "set of questions regarding one or more variables to be measured",[17] as the questions to be asked directly to the students are related to the variables described in Chapter I, but at the same time will have a direct logical connection between the problem described and the hypothesis proposed for the research.

Procedure

The results of the validation of the operationalization of variables and the instruments to be applied in the research on the "Planning, design, and execution of STEAM projects using the flipped classroom methodology for students in the General Unified Baccalaureate program in the subject of Biology at the 10 de Agosto Public School during the 2024-2025 school year. This validation has been carried out through the review of three experts in the field of education and, above all, with experience in teaching practice, who have evaluated the relevance and adequacy of the dimensions and indicators of each variable.

To carry out the validation, three experts with extensive experience in pedagogy were selected. The validation process "aims to facilitate the measurement or observation process, as well as make it much more accurate and reliable"[22] to determine its measurement, for which the following was included:

Documentation Review: the experts were presented with the topic, objectives, problem formulation, and variables described for the research proposal, which included the operationalization of variables and the design of data collection instruments (survey of teachers and students).

Evaluation of Dimensions, Indicators, and Instruments: each expert evaluated the dimensions and indicators proposed for the variables (VD: Flipped Classroom Methodology, VI: Planning, Design, and Execution of STEAM

Projects), providing feedback on their clarity, relevance, and appropriateness to the educational context without neglecting the validation of the instrument to be applied to the research subjects.

General observations: the experts provided general observations on the relevance of the flipped classroom methodology applied in the STEAM project, noting that the application of the surveys is feasible due to its logical sequence with the variables and dimensions described.

The variables evaluated in the research include:

- Dependent Variable: Planning, Design, and Execution of STEAM Projects.
- Independent Variable: Flipped Classroom Methodology.

The experts agreed that the dimensions and indicators established for each variable are appropriate and relevant to the research context. The following observations were highlighted:

In the opinion of expert No. 1, the variables and their dimensions are appropriate and show a relationship with the items proposed; hence, she states that the indicators are geared towards the conceptualization of the research we have proposed. She also observes the form, suggesting that the spelling of a term be reviewed. However, this does not indicate that a change should be made in either the variable matrix or the instrument proposed for teachers and students.

The observations of expert No. 2, on the other hand, range from the formulation of the problem and the objectives. He recommends revising certain terms in these sections to improve the clarity of the research. Regarding the variable matrix, he observes that if the dependent variable has three dimensions, the matrix should have the exact three dimensions and start from there to develop the indicators.

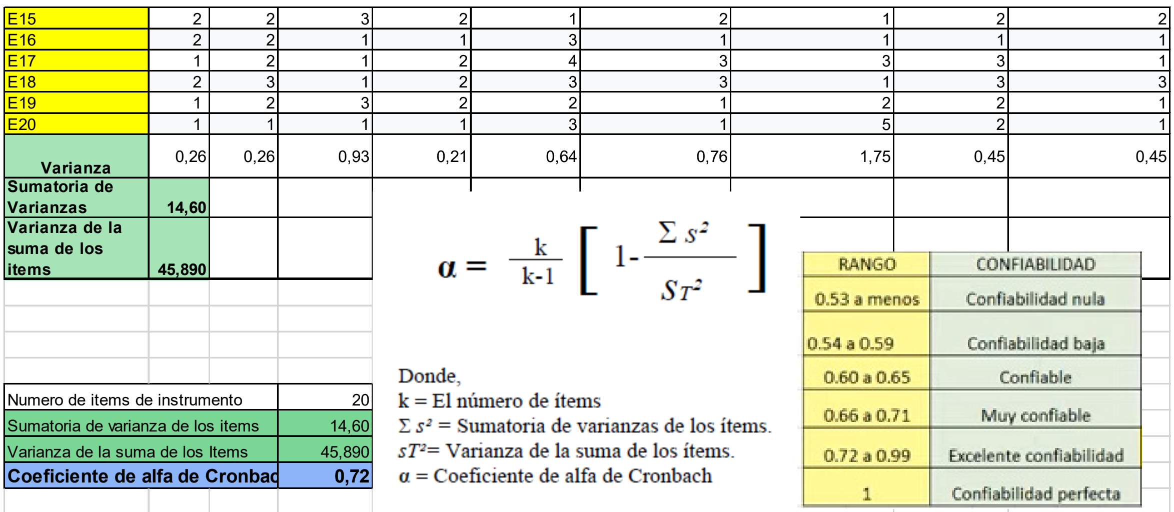
For the questionnaire, observations indicate that some questions relate to the indicators, one question is duplicated, and another could measure experience rather than lack of training in STEAM project development. These changes have undoubtedly been applied in the development of these instruments following her observations to comply with the formulation of the problem and the objectives set, which are undoubtedly a valuable contribution to this research.

The observation of expert No. 3 suggests that other questions could be included to reinforce the information, and that open-ended questions could be included to elicit more detailed responses from respondents. However, she acknowledges that the instruments are clear, coherent, and precise for data collection, helping to obtain relevant information in the research process. Therefore, she agrees that there is clarity in the dimensions, which will facilitate data collection and subsequent analysis.

Cronbach's alpha to verify the statistical validity of the instruments

In addition, the instruments were validated using Cronbach's alpha, which allows us to verify how reliable the instruments are. To perform this verification, Excel was used with the formulas determined for this case, giving us a fairly reliable percentage, which also allows us to apply these instruments to teachers and students at the institution where the research is being conducted, which corresponds to the 10 de Agosto Fiscal Educational Unit in the city of Quito.

For students, Cronbach's alpha, which is the value that allows us to estimate the reliability of a data collection instrument through a set of items,[23] gives us a value of (0,72) emphasizing that the higher the coefficient (between 0 and 1), the greater the reliability, for which the scale in figure 2 is used as a guide, which by deduction affirms that the instrument is of excellent reliability.[24]



E15	2	2	3	2	1	2	1	2	2
E16	2	2	1	1	3	1	1	1	1
E17	1	2	1	2	4	3	3	3	1
E18	2	3	1	2	3	3	1	3	3
E19	1	2	3	2	2	1	2	2	1
E20	1	1	1	1	3	1	5	2	1
Varianza	0,26	0,26	0,93	0,21	0,64	0,76	1,75	0,45	0,45
Sumatoria de Varianzas	14,60								
Varianza de la suma de los items	45,890								

Numero de items de instrumento	20
Sumatoria de varianza de los items	14,60
Varianza de la suma de los Items	45,890
Coeficiente de alfa de Cronbac	**0,72**

$$\alpha = \frac{k}{k-1}\left[1-\frac{\sum s^2}{S_T^2}\right]$$

Donde,
k = El número de ítems
$\sum s^2$ = Sumatoria de varianzas de los ítems.
sT^2= Varianza de la suma de los ítems.
α = Coeficiente de alfa de Cronbach

RANGO	CONFIABILIDAD
0.53 a menos	Confiabilidad nula
0.54 a 0.59	Confiabilidad baja
0.60 a 0.65	Confiable
0.66 a 0.71	Muy confiable
0.72 a 0.99	Excelente confiabilidad
1	Confiabilidad perfecta

Figure 2. Results of the instrument validation

Meanwhile, for teachers, Cronbach's alpha gives us a value of (0,70), which, following the scale in the image,[24] would indicate that the instrument is very reliable for its application.

D16	1,00	1	2	2	2	3	5	3	3	2
D17	3,00	1	3	3	3	2	1	3	5	3
D18	2,00	2	3	3	3	3	1	1	1	2
D19	1,00	2	3	3	3	3	1	1	4	4
D20	1,00	2	3	3	3	3	1	1	4	4
Varianza	1,29	0,56	0,64	0,61	0,64	0,99	2,33	0,71	3,74	1,21
Sumatoria de Varianzas	**24,57**									
Varianza de la suma de los items	**74,0475**									

Numero de items de instrumento	20
Sumatoria de varianza de los items	24,57
Varianza de la suma de los Items	74,0475
Coeficiente de alfa de Cronbach	**0,70**

$$\alpha = \frac{k}{k-1}\left[1 - \frac{\sum s^2}{S_T^2}\right]$$

Donde,
k = El número de ítems
$\sum s^2$ = Sumatoria de varianzas de los ítems.
sT^2= Varianza de la suma de los ítems.
α = Coeficiente de alfa de Cronbach

RANGO	CONFIABILIDAD
0.53 a menos	Confiabilidad nula
0.54 a 0.59	Confiabilidad baja
0.60 a 0.65	Confiable
0.66 a 0.71	Muy confiable
0.72 a 0.99	Excelente confiabilidad
1	Confiabilidad perfecta

Figure 3. Application of Cronbach's alpha to the teacher survey

The validation of the operationalization of variables and instruments for research on the planning, design, and execution of STEAM projects using the flipped classroom methodology has been successful.

The review carried out by the experts has confirmed that the dimensions and indicators of each variable are appropriate, as well as their relevance for working on STEAM projects using the flipped classroom.

Cronbach's alpha indicates that the instruments have a reliability level between very reliable and excellent, making them directly applicable to the research subjects.

RESULTS

Data collection was carried out using a survey technique with a questionnaire, which was administered to teachers and students based on the indicators established in the analysis of the variables. It is important to mention that in the Natural Sciences area of the institution, the unit of analysis of this study, there are four teachers, so it was decided and proposed to administer the survey to all teachers in the afternoon session (upper elementary and high school) in order to obtain a broader assessment of perceptions regarding the application, design, and execution of STEAM projects, considering the positive and negative factors that facilitate proposing the guide as a viable alternative solution to the problem, where the flipped classroom methodology is an indispensable tool for carrying out STEAM projects.

The survey was conducted for 22 teachers (afternoon shift) with a total of 22 questions measuring the indicators of the variables Flipped classroom methodology (independent variable) and the planning, design, and execution of STEAM projects (dependent variable) with several dimensions for the study, where it was possible to determine teachers' perceptions of this issue and contrast their opinions with the reality of their work with STEAM projects.

Within the educational institution, STEAM projects have been developed in previous years, but due to a lack of in-depth knowledge of the approach and strategies that can be used, as well as the methodology that can be applied to develop and implement them in the best way possible, they have not been given the necessary importance, nor has there been sufficient training to develop them with all the rigor that this implies. Therefore, the study will identify strengths and weaknesses as a basis for addressing this problem, as new alternatives are developed to ensure that it is implemented more effectively and accurately.

As for the students, the survey was conducted with students in the first, second, and third years of the General Unified Baccalaureate (BGU) program. A total of 20 questions were asked, including sociodemographic data such as age, gender, and grade level, with a total of 126 respondents. This allowed us to obtain favorable results regarding the problem under investigation. Based on the respective explanation and socialization of the study, the objective of the survey, and the purposes of the items.

Analysis and Interpretation of Data from the Student Survey

When reviewing the data from the respondents, it can be shown that the vast majority are aware of and familiar with the subjects they work on in the STEAM project, with more than 50 % responding affirmatively, which shows that the students have worked on these projects and have an idea of how to implement them in the classroom with the students.

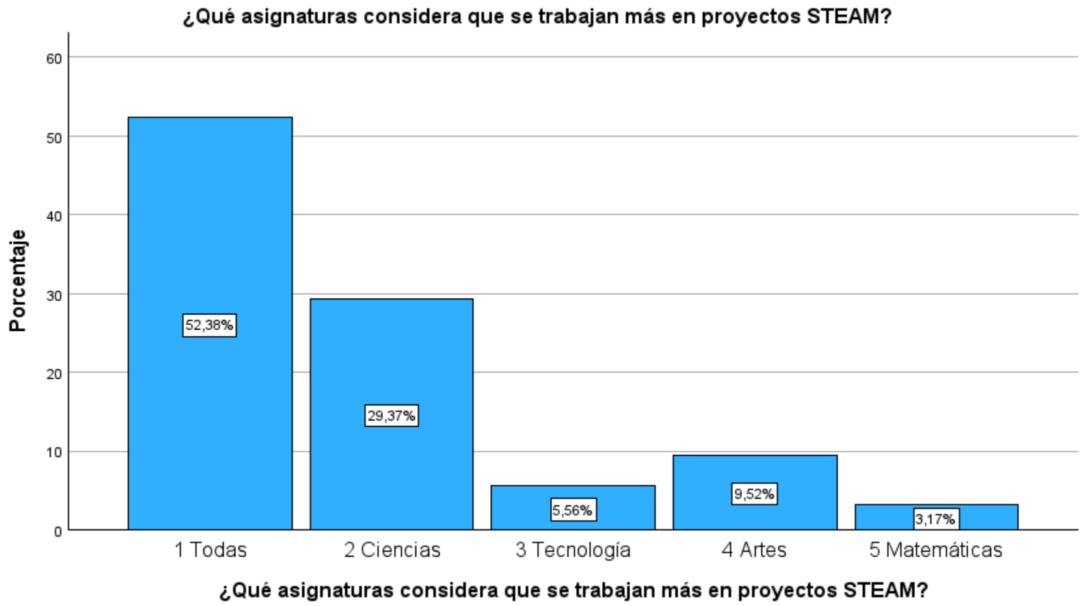


Figure 4. Subjects where the STEAM project is mainly worked on

Then there is a significant percentage (29 %) who say that they work more in science, suggesting that they are referring to work in the subject of Biology, which demonstrates the work carried out in the area of Natural Sciences. It is therefore considered important to continue strengthening the management of these projects using new innovative methodologies in the subject of Biology, bringing the curriculum closer to reality, such as explaining phenomena, however strange they may seem.[7]

Resumen de procesamiento de casos

		Número de estudiantes	Porcentaje
¿Qué tan motivado se siente al trabajar en proyectos que combinan varias asignaturas?	1 Muy motivado	29	23,0%
	2 Motivado	60	47,6%
	3 Poco motivado	27	21,4%
	4 Nada motivado	10	7,9%
¿Qué herramientas prefiere utilizar en proyectos STEAM?	1 Computadora y teléfonos	44	34,9%
	2 Materiales prácticos	27	21,4%
	3 Herramientas tecnológicas	23	18,3%
	4 Actividades didácticas	20	15,9%
	5 Actividades mediadas por el aprendizaje autónomo	7	5,6%
	6 Otras:	5	4,0%
¿Considera que aprender en casa con recursos tecnológicos le ayuda a entender mejor los proyectos STEAM?	1 Siempre	20	15,9%
	2 Frecuentemente	54	42,9%
	3 Ocasionalmente	43	34,1%
	4 Nunca	9	7,1%
¿Qué tipo de recursos tecnológicos le gustaría tener para trabajar en proyectos STEAM?	1 Videos tutoriales	40	31,7%
	2 Software especializados	15	11,9%
	3 Guías y tutoriales	27	21,4%
	4 Actividades diseñadas para el aprendizaje autónomo mediadas por las tecnologías y el trabajo en equipo	40	31,7%
	5 Otras: ____________	4	3,2%
Válidos		126	100,0%
Perdidos		0	
Total		126	
Subpoblación		57[a]	

a. La variable dependiente sólo tiene un valor observado en 37 (64,9%) subpoblaciones.

Figure 5. Data from the survey administered to students

An analysis of the data grouped in the figure above shows that more than 60 % of students feel motivated and highly motivated when working on interdisciplinary activities, i.e., those involving several subjects and the use of technological tools in and outside the classroom. Similarly, more than 80 % prefer to use technological tools and resources such as computers, cell phones, video tutorials, platforms, and applications, among others, which serve as a guide for independent or collaborative work and, in turn, motivate them to work on STEAM projects.

According to the study by Pertuz et al.[25], they recognize that technological tools are practical when using the STEAM approach. It is understood that, being surrounded by technology, they want to work with these types of resources so as not to disconnect from the reality of the 21st century. However, a considerable number of students argue that relying on technological tools for learning activities at home is not always the most effective solution for developing STEAM projects, particularly in light of the current reality of families experiencing power cuts of up to 3 to 5 hours a day.

The possibility of working with practical materials, such as short readings, infographics, leaflets, or educational activities, is considered, which the teacher could send as short readings, infographics, leaflets, or educational activities for the manipulation and direct implementation of the project contributions without the need for technology. However, the motivation and preference of students for carrying out activities with technological resources are relevant in most cases.

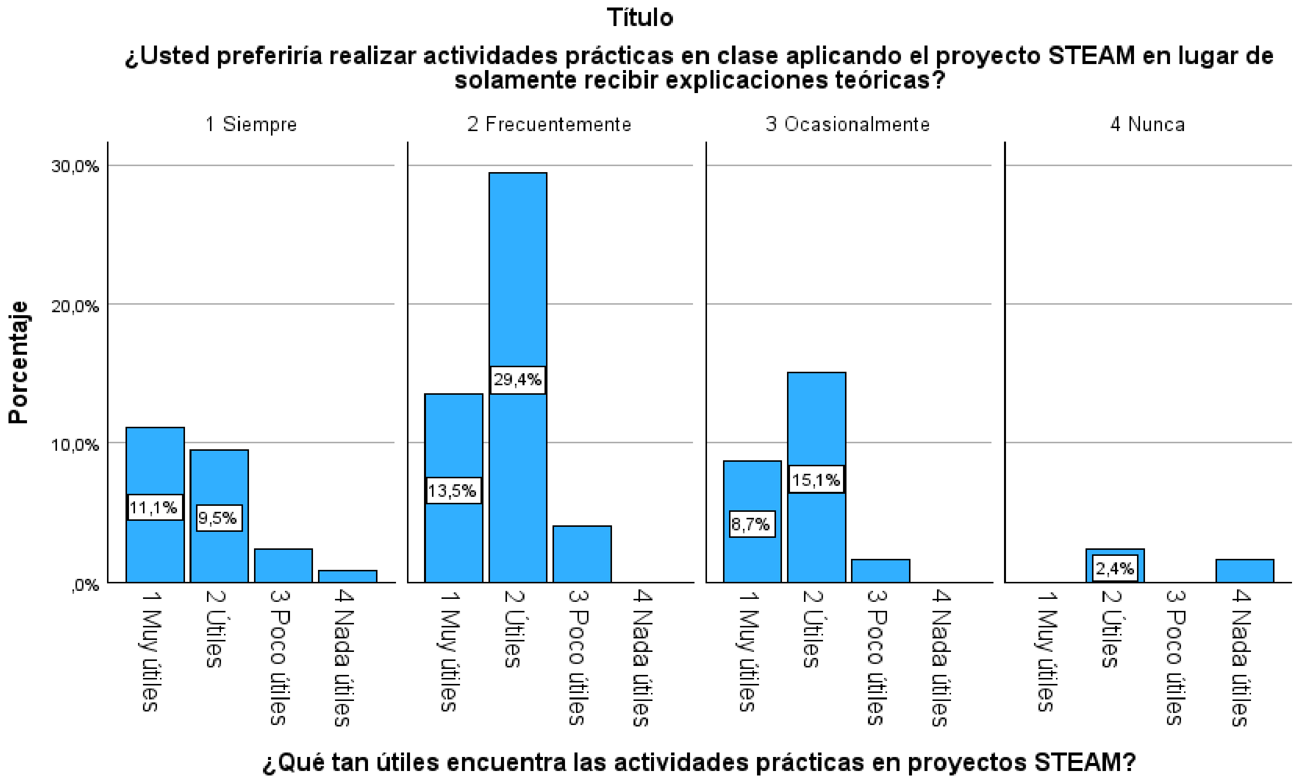


Figure 6. Practical activities applying the STEAM project and level of usefulness

This comparative figure shows that students prefer practical activities to be carried out always, frequently, or occasionally for the development of STEAM projects, considering that 90% of respondents stated that these types of activities are beneficial in the development of STEAM projects, understanding that theoretical classes in any subject will always be less motivating for them. Therefore, they prefer to carry out this type of practical work, which involves students being active and working in teams in a collaborative and interdisciplinary manner.

This confirms that interactive activities are efficient and motivating for students, with technology being a viable tool for such purposes, as stated by Pertuz et al.[25], who affirm that the use of technological tools to achieve educational goals will have positive results and may even respond to the current needs of society. The analysis based on the students' opinions shows that when teachers have carried out STEAM projects, 90 % say that it has often or occasionally been easy to develop a final product to present at the end of the project. While also believing that using the flipped classroom could improve the development of the project itself and the final product, solving problems and serving as an active methodology for teachers because the flipped classroom promises to be more enriching than traditional methodologies, as it allows questions to be asked and reasoned answers to be obtained[26] and, above all, practical activities can be carried out in the classroom.

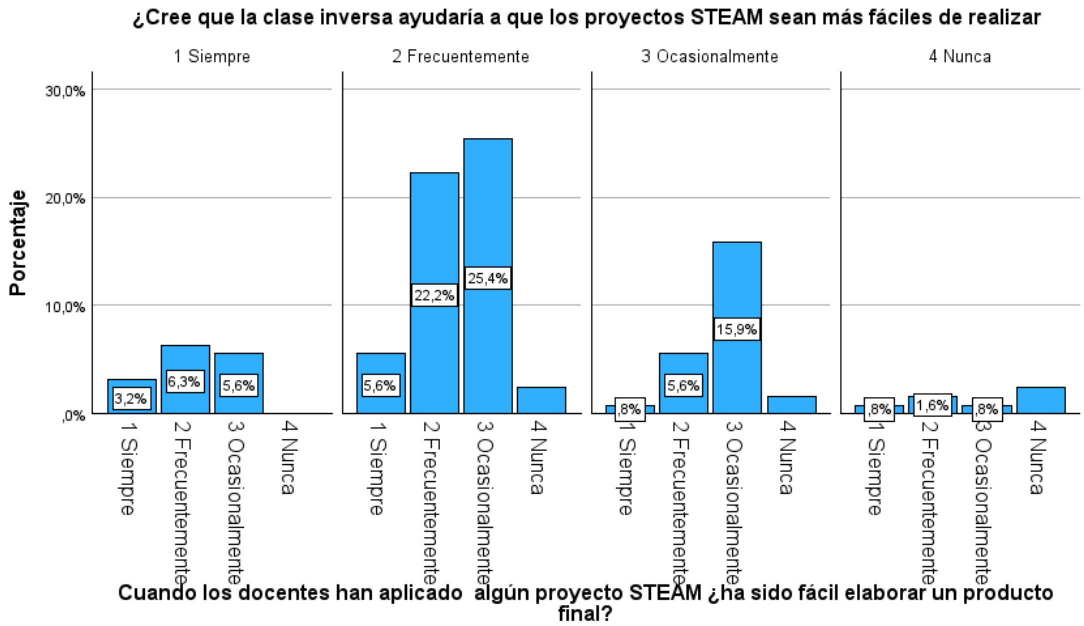


Figure 7. Contributions of the flipped classroom to the development of STEAM projects

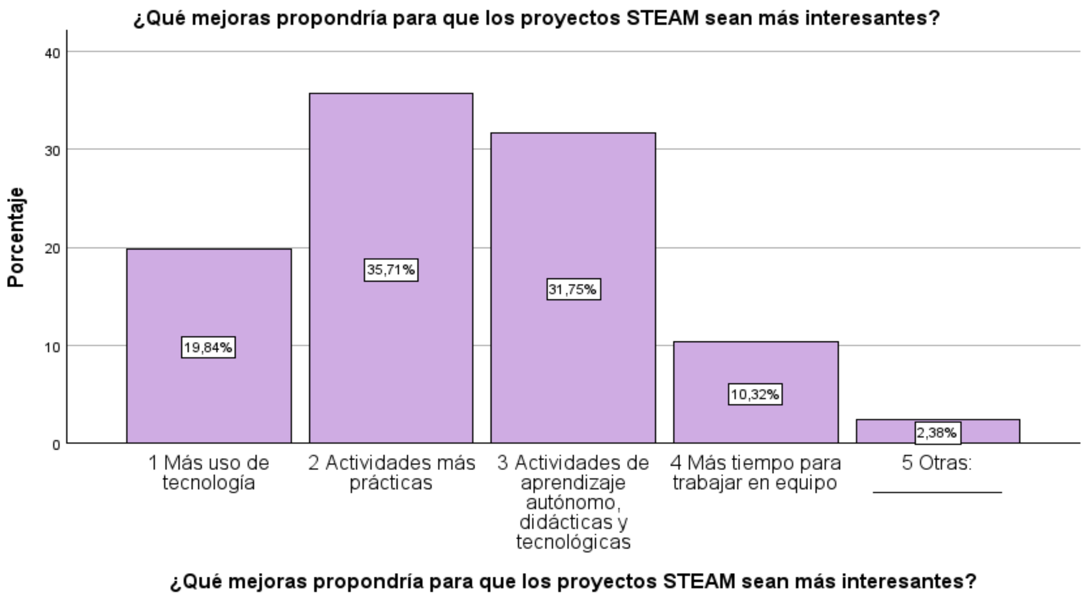


Figure 8. Alternatives proposed to make STEAM projects more interesting

When asked about alternatives to make STEAM projects more interesting, students' opinions were divided, with the vast majority (36 %) stating that more practical activities would be helpful to, counterbalancing the responses, where they indicated the usefulness of teaching activities and practical materials to improve their learning by giving more meaning to classwork with STEAM projects.

On the other hand, 42 % of students indicate that the use of technology is essential to improve activities in the development of STEAM projects because they see the need to have a cell phone or a computer to carry out their activities guided towards autonomous learning, since technology supports the development of "STEAM skills and competencies"(27) when using a technological device or tool that serves as a medium in the teaching-learning process, but which is also of interest to students so that they feel motivated. Comparing figures 5 and 6 reveals that the most significant challenges students face in completing the STEAM project are insufficient time, limited resources, difficulties in grasping the concepts, and restricted classroom space. However, the fact that interactive materials such as videos and readings are part of the practical activities can be complementary when carrying out the STEAM project. As it is an interdisciplinary project, it must be designed with a wide range of practical and educational activities in mind that can be carried out both inside and outside the classroom.

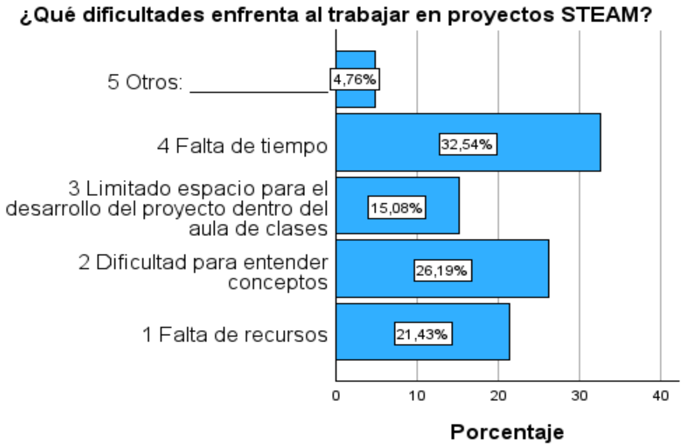


Figure 9. Respondents' opinions on the difficulty of working on the STEAM project

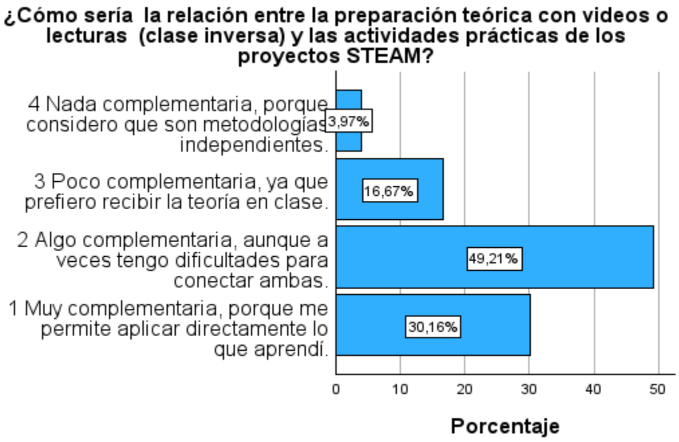


Figure 10. Relationship between the theoretical preparation of the flipped classroom and the practical activities of the STEAM project

That is why it is complemented with the flipped classroom, sending readings and videos for prior preparation, because "with interactive materials, it allows students to develop creativity and motivation".[28] However, 30 % believe that it is very complementary to applying what has been learned, and 49 % say that something could be added because it makes it difficult to connect the STEAM project with the flipped classroom methodology.

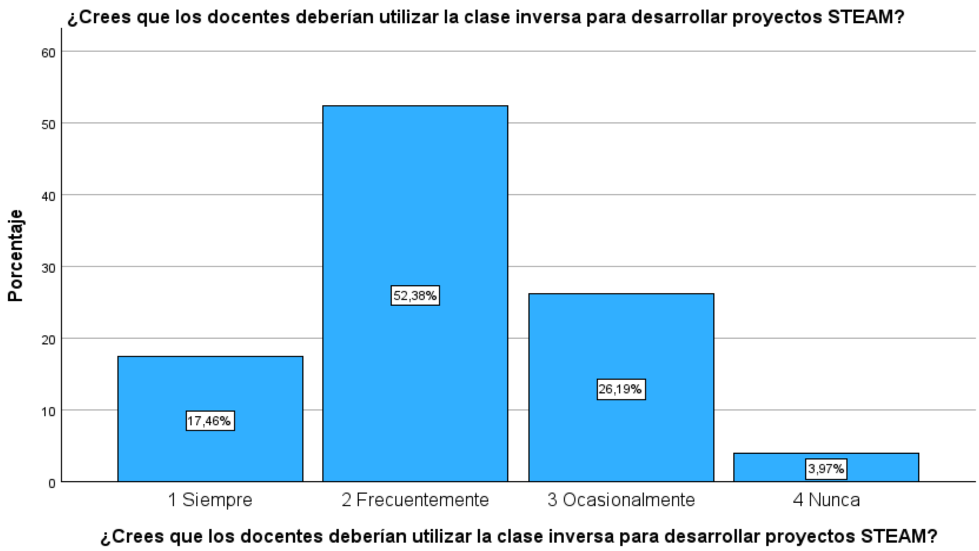


Figure 11. Use of the flipped classroom by teachers to develop STEAM projects

When reviewing student data, we observe a trend indicating that teachers should utilize the flipped classroom approach both frequently and occasionally as an alternative for developing STEAM projects. In this regard, Rodríguez et al.[8] point out in their studies that when using the flipped classroom, there has been a high level of acceptance among students compared to other traditional methodologies.

Understanding that this is a methodology that will allow students to work both in the classroom and at home with activities for prior preparation that can involve the use of technological tools as well as recreational activities where they can practice and develop their skills, it is understandable that they do not always want a single methodology to be used all the time, as it would also be very tiring for teachers not to change their strategies.

Hypothesis testing

Table 1. Normality tests

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**Gl**	**Sig.**	**Statistic**	**Gl**	**Sig.**
Dependent variable	0,122	18	0,200*	0,971	18	0,810
Independent V	0,107	18	0,200*	0,969	18	0,783

*. This is a lower limit of true significance.
a. Lilliefors significance correction

Research Hypothesis

The application, design, and implementation of the STEAM project may be feasible with the use of the flipped classroom methodology. To test the hypothesis and the normality test, 13 responses corresponding to the dependent variable from the teacher survey results and 12 responses from the student survey were grouped. For the independent variable, six responses from the teacher survey and seven responses from the student questionnaire were grouped. This grouping provides greater clarity.

The results of the normality test, which "serves to check whether the values of a variable follow a normal distribution or not"[29] in this research project, allow us to verify whether the hypothesis is null (Ho) or alternative. Reviewing the data shows that it is possible to propose a null hypothesis because the value of ρ (0,200) for the DV and (0,200) for the IV is greater than the significance of ρ (0,05).[29] Therefore, it can be stated that the values in this survey followed a normal distribution.

Therefore, it is determined that a Parametric Test should be applied, as suggested by Ponce et al.[30], which is based on a standard distribution because it analyzes the elements of a sample. In contrast, if it were a Non-parametric test, it would have to measure the level of discrepancy.[31] Based on the number of students surveyed according to the figure, we determined that the Kolmogorov-Smirnov test should be applied, which explains that "they generally lead to non-Gaussian distributions and, therefore, the generating mechanism of the processes can be better understood by examining the distribution of the selected variables"[32] as a statistical criterion.

Correlaciones

		variabledependiente	Vindependiente
variabledependiente	Correlación de Pearson	1	,242
	Sig. (bilateral)		,334
	N	18	18
Vindependiente	Correlación de Pearson	,242	1
	Sig. (bilateral)	,334	
	N	18	18

Figure 12. Pearson's parametric test

When comparing the figures of Pearson's parametric tests, it can be seen that the correlation between the dependent and independent variables is (1) to (0,242) and, similarly, the correlation between the independent and dependent variables is (0,242) to (1). Therefore, according to Ortega's statement (December 25, 2024), it can be clarified that the correlation is greater than zero; therefore, the variables are directly correlated, and it is a positive correlation.

This research was conducted with students from the General Unified Baccalaureate Program at the 10 de Agosto Public School in Quito, with a total of 126 male and female respondents, with an age range for first-year

BGU students between 14 and 15 years old. In contrast, the age range for second-year BGU students is 16 to 17 years old, and for third-year BGU students, it is 16 to 18 years old. This means that most of the students are within the recommended age range according to data from the Ministry of Education.[33]

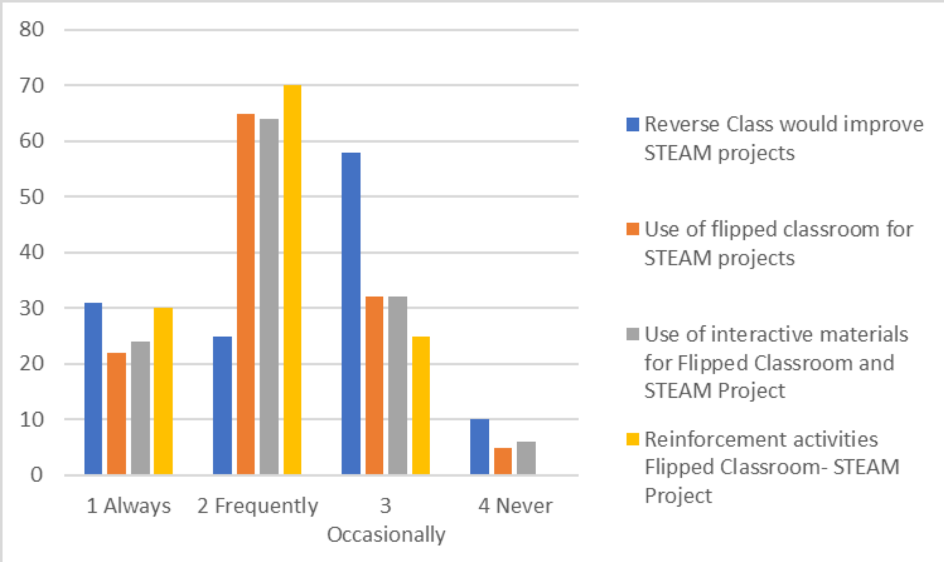


Figure 13. Students surveyed

How students view teachers' use of the flipped classroom methodology for the development of the STEAM Project

According to the students surveyed, integrating the flipped classroom to develop STEAM projects is positive because it improves their learning compared to traditional methods. In addition, this methodology encourages the use of audiovisual materials that cater to individual needs during the teaching-learning process. It also fosters autonomous and research activities for young people, enabling them to develop interdisciplinary projects, such as the STEAM Project, through the flipped classroom approach.

According to the graph, students agree that the flipped classroom should be used as an active methodology for developing STEAM projects because it also encourages students to be fundamental participants in the construction of knowledge. This improves significantly when students can analyze what they have learned because they have not only received information, but have been part of that construction, which will serve to make learning lasting and meaningful.

According to the students, they mention that it is positive and teachers have used some interactive materials to develop the flipped classroom and, in turn, create STEAM projects. This type of strategy in the flipped classroom enables students to leverage prior knowledge and build, for example, a hologram box, using materials provided in advance by teachers, such as videos, readings, images, slides, and infographics.

Likewise, when creating STEAM projects using the flipped classroom methodology, the graph shows that teachers carry out autonomous and research activities as part of the reinforcement activities for this purpose in a high percentage, because students must not be just recipients of information but rather builders of knowledge. This will help develop a product that helps solve a real-life problem at the end of the STEAM project.

Proposal

The product to be presented is an Interactive Guide containing a proposal on how to develop the STEAM Project using the flipped classroom method, which brings about significant changes in teaching methodology with a transformative vision in educational centers.[34] On this occasion, the theme "Exploring human evolution with holograms" has been developed. By carrying out this proposal, students will be able to create a product to solve a problem in their social or educational environment. By utilizing technological tools, instruments, and strategies in survey analysis, students will be motivated and develop a new attitude.

Defining activities that they can do at home to advance their work in class will be a fundamental point for students to continue the learning process inside and outside the classroom, «which allows for more personalized interaction between the teacher and the student and stimulates independent work by students».[35] The activities will help students read, observe, analyze, and work in an interdisciplinary manner, that is, apply knowledge from different areas in a single product that is presented at the end of the process, and explain how each area is functionally integrated.

On the other hand, teachers implementing a STEAM project will be able to develop it better by applying the flipped classroom methodology because it promotes active student participation, learning through experience, the construction of their knowledge, the use of technological tools and strategies that facilitate participation and collaborative work, and encourages each student to have a different role to play in the different stages of the STEAM project, where the teacher becomes a guide and mediator of learning, providing feedback in each class to reinforce this knowledge.

This interactive teaching guide aims to address the pedagogical practices that teachers use in their daily work to maintain students' attention, "inquire, appropriate, transmit, and employ concepts and processes specific to the areas that comprise it within environments that foster collaboration and inclusivity",[36] making the class more participatory and active, motivating students to work on interdisciplinary projects that bring together different subjects and allowing them to present a final product so that it is not just a theoretical class. In addition, this type of project can be an opportunity for students to demonstrate their skills.

The lack of teacher training means that there is no motivation to develop projects that can solve a problem in the students' social and educational context. Therefore, this interactive guide provides user-friendly and straightforward guidance on how to build a STEAM project using the flipped classroom methodology, so that teachers can plan interactive homework activities and proactive classroom activities with students to enable them to apply their knowledge in everyday life and at school.

This interactive guide proposes the use of technology with materials and resources that employ technological strategies and tools such as videos, short readings, infographics, assessment platforms, and learning games, as these proposals for the use of digital tools have become more widespread since the pandemic and students are very attracted to this type of resource because they are familiar with them and find them very easy to use for educational and learning purposes, which can help teachers to advance with the content programmed in their plans.

In addition to serving as a planning guide for teachers, it also functions as a study guide for students. They can follow the activities without losing track of their progress and have the opportunity to explore this teaching guide on their own, as it is easy to use. If they encounter any difficulties attending classes, this will serve as their primary source of information to continue advancing with the content and developing the Performance Criteria Skills (DCD) by applying communication and technological skills directly to their learning.

The proposal is based on the Google Sites tool, through which learning activities aimed at BGU students are presented. This digital resource was chosen because it is easy to access each of the sections that make it up, allowing each topic, link, or material to be organized according to the study schedule. According to the study schedule. It also allows direct linking to specific activities for students to complete their assigned tasks as a commitment and to monitor their academic performance.[37]

Below are the steps to create a digital space as a teaching guide for the Natural Sciences content on the topic of Human Evolution: The Process of Hominization, entitled "Exploring Human Evolution with Holograms."

- Open the Google Chrome search engine, type Google Sites in the search bar, and click on the first option.

It should be noted that having an active Gmail account will facilitate direct access to the tool.

- Once you are in the resource, you will see an option that says "create a site" with a colorful plus icon. Click on this icon, as it indicates a blank site.
- Next, enter the title of the page, in this case "Exploring human evolution with holograms."
- On the right-hand side, there is a section with three options: insert, page, and themes. In the insert section, choose the shape of the content block. In the page section, use the purple plus sign to create the five windows that organize the sections of the teaching guide. These five windows are: programming, multimedia preparation, sequencing of time outside the classroom, design of classroom sessions, and distribution of the rest of the time. In the third option, choose the purple theme with a simple style.
- Next, according to the five windows created, the corresponding study information is added.

DISCUSSION

In line with the first group of analysis, which is teachers, some points are presented that are taken from the section on analysis and interpretation of results. It should be noted that three aspects are considered that allow the variables that make up this study to be expressed in an organized manner. Each of these is detailed below.[48,49,50,51,52]

The institution boasts a large number of teachers with over five years of experience in education, as well as those from various knowledge areas who have, at some point in their professional careers, implemented the STEAM project. Among the teachers with experience and those without, they were required to lead the classroom in applying this type of interdisciplinary project correctly. Thus, in the study by Pazmiño et al.[38], they state that teachers must have leadership to bring about positive change in educational environments so that the teaching-learning process can be adequately developed.[53,54,55,56,57,58]

Use and application of STEAM projects: the most relevant aspects to mention are that teachers are familiar with the use of STEAM projects; however, they indicate that the most significant difficulty in implementing this project is the lack of training. This means that they do not have all the tools to develop this project effectively. According to Rodríguez et al.[5] in their study on STEAM methodology in educational environments, they emphasize that, as this project is transdisciplinary, other sciences must also be articulated in order to obtain benefits, especially by making use of technological tools, which creates an appropriate environment that promotes interaction with other subjects and meaningful learning.[59,60,61,62,63]

However, faced with this challenge, some teachers have used the flipped classroom methodology in their practice and are aware of its high impact on the development of research skills and abilities, as agreed by Chicaiza et al.[39], who conducted research in secondary schools to investigate the benefits of implementing the flipped classroom, concluding that it offers significant benefits that will lead to challenges and collaborative information seeking, where participation is more than just collecting data. Therefore, autonomous learning will also take precedence and influence student participation, leading to innovation in academic development.[64,65,66,67,68,69]

Flipped Classroom and STEAM Project: teachers recognize that there is complementarity and mutual support between the flipped classroom methodology and the STEAM project. Gorosito[40] points out that "the flipped classroom is a mixed methodology that combines face-to-face and digital learning, and the roles of teachers and students are reversed." One of the benefits of applying both educational aspects is the learning and development of students, both in person in the classroom and at home digitally, with specific activities that contribute to the development of learning.[70,71,72]

For Torres et al.[41], the implementation of the project shows the coordination between the different disciplines and how each one becomes part of a whole, approaching knowledge in a holistic way that promotes the comprehensive training of students. However, the institution's lack of technological resources could limit the effectiveness of STEAM project development and implementation, which is why it is stated that there is little support from the educational institution.[73,74,75,76]

CONCLUSIONS

According to the theoretical framework, the STEAM project is an interdisciplinary approach, integrating various disciplines such as science, technology, engineering, mathematics, and art. This suggests that the approach does not prioritize individualized learning, but rather relatively integrated and constructive learning, which is facilitated by the flipped classroom. This is characterized by emphasizing the student's role in various ways, such as through peer work and role reversal, thereby moving away from traditional learning methods.

There is acceptance of the relevance of implementing the STEAM project and the flipped classroom, as it improves learning, motivates students, and leads to autonomous learning. In addition, teachers are aware of the use of the STEAM project and the flipped classroom to develop their classes in different subjects, so its application is not limited to biology. However, the practice of both educational aspects (STEAM project and flipped classroom) in the learning process is occasional, meaning that teachers have the experience but do not always use it. This situation arises because they lack the necessary training, resources (such as technology), or institutional support.

In response to the educational context in which the research is carried out, a plan has been designed that reflects the proposal as a teaching guide to orient the implementation of a STEAM project and the flipped classroom using the Google Sites tool, which highlights the components, content, references, and structure of the proposal, considering the topic of human evolution: the process of hominization, all of this projected through technological tools. This space allows interaction with study activities aimed at BGU students.

To validate the proposal, expert criteria are used, where teachers with experience and knowledge are selected, not only in the subject of study or biology, but also who are knowledgeable about the educational context and, therefore, the reality of that space. Based on this, a positive acceptance was obtained from these experts, due to the content which, in their opinion, is appropriate and in line with the objective of this study.

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