Workshop evaluating the systems integration of a CubeSat as an effective tool for STEAM education, a case study of work in progress.

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Abstract

After a successful launch and deployment of the first Paraguayan satellite, a CubeSat style, the GuaraniSat, public attention on how the New Space era is reaching this country was evidenced. This historical event helped inspire students to be involved in STEM. This was the motivation to design a workshop on nanosatellite system integration. With this, we expected improvements in teaching engineering fundamentals to college students. Space-related educational programs have grown in popularity as a motivating way to teach STEM subjects. Past CanSat (Can-Satellite) training program for teachers was proven to be effective in motivating students into STEM. In this work, a similar teaching approach was conducted. This time, a CubeSat-style prototype for educational purposes was used. Students were trained under this platform on subsystem integration and operations. This workshop was intended to teach engineering fundamentals such as sensor principles, signal conditioning systems, data acquisition fundamentals, and graphical user interface theory to a senior-level engineering student. This study aims to measure students learning performance as they learn on each satellite subsystem working principles and how all of this is integrated and operated from a friendly graphical user interface. Indicators such as the following will be used to assess the impact on learning effectiveness: Experimentation and Iteration, Trial and Debugging, Reusing and Remixing, Abstraction and Modularization and will be scored as low, medium, or high. In addition, problem-solving abilities based on the Polya method will be taken into account. The process is categorized into problem comprehension, plan set up, plan execution, and obtained solution analysis. All evaluation procedures are based on engineering design competencies.

Keywords
Usability, Didactic Module Prototype, CubeSat, STEAM Education.

1. Introduction
The STEAM approach and Aerospace Education have had a positive impact in recent years in Paraguay, especially with the launch and placement into the orbit of the CubeSat style the GuaraníSat1 in 2021 (AEP, 2021), being one of the most significant technological achievements in the country. This experience developed a series of hands-on classes on the application of a didactic module in the assembly and operation of this nanosatellite.

The here referred CubeSat is a didactic module prototype. This was designed for the development of nanosatellites whose main objective is to apply space science in the education sector through a project-based learning methodology.

Previous research was carried out in Paraguay, such as a CanSat project (Kurita et al, 2020), where high school instructors were involved in the challenge of building a "very small and simple satellite" (a picosatellite). This satellite contained characteristics similar to those of larger satellites. The teachers learned to plan, design, and solve problems related to the process of building a real space mission, which is one of their main objectives.

One of the most relevant didactic strategies incorporated in pedagogical mediation in CubeSat's aerospace education is Project-Based Learning (PBL), conceived as a leading methodology that aims to develop hard skills in students so that they can solve problems or challenges by actively participating in the process of solution-finding.

Therefore, when dealing with teaching strategies in the STEAM area, an approach that integrates and encourages the interest of students in the areas of science, technology, engineering, arts, and mathematics is needed. This methodology allows for the development of different soft skills in students, from real situations to problem-solving.

In this sense, the objective of this research was to measure how students react to the incorporation of a prototype of a didactic module called CubeSat that was used as a support tool for STEAM teaching.

Therefore, the didactic modules proposed pedagogical resources that favor the teaching-learning process, which consisted of incorporating into the classroom a challenge to be solved with the CubeSat prototype and assembling a satellite in the undergraduate engineering course under the supervision of their instructor.

This experience improves the teaching part of its role as facilitator and counselor, in their hands-on classes. Here, students who participated in the practice had the opportunity to analyze the assembly process step by step, using the inquiry and implementation as an active learning methodology.

The questions were consigned to relate what they learned in theory with what they gave away in practice, seeking that they can establish skills of experimentation and iteration, testing and debugging, reuse and reinvention, abstraction, and modularization.

2. Methods
Regarding methodology, the present case study used applied research, organized in experiential workshops in pedagogical spaces specifically for the understanding of the construction and use of CubeSat. The logical reasoning method used was inductive, deductive, hypothetical, analytical, and synthetic. Likewise, the scope of the study was adjusted to the exploratory-descriptive levels, while the approach corresponded to the mixed (qualitative), cross-sectional period, and quasi-experimental design.

The validation of the data collection instrument was carried out through a test applied to analysis units with similar characteristics, where the analysis and consistency of the indicators were carried out. It should be noted that this instrument is based on the proposals of Brennan K., Balch C., Chung M., of the Harvard Graduate School of Education and applied research by Ortiz Coronel D., Kurita J., Moreira L., Stalder D., Vega B., and Moreira M., (2020) on CanSat aerospace teaching projects, which served as background for the research. This study is not intended to demonstrate that a CubeSat is better than a CanSat as a training tool, but rather, to refer to previous research that was conducted on instructors.

The student sample was composed of 9 individuals from the 3rd (Senior) year of the Electromechanical Engineering course of a Private University in Paraguay. Sampling was adjusted to the type of non-probabilistic convenience; the inclusion criteria were individuals of both sexes, students of the indicated semester, university students with basic programming knowledge, on the other hand, the established exclusion criteria: students from younger years, students who could not attend the workshops, people who did not want to participate in the workshops.

About the stages of the process of implementation of the experience, they were mainly based on the following:

- Definition of fundamental concepts of space sciences.
- Definition of fundamental engineering concepts in manufacturing systems and processes.
- Definition of fundamental software concepts for control and data acquisition systems.
- Demonstration of the components of the didactic prototype comparing with the concepts previously studied.
- Demonstration of prototype implementation.
- Demonstration of the use and application of software with GUI for data monitoring and control.
- Comparison of the data acquired with measuring instruments.
- Evaluation of experience.

The variables studied addressed four criteria: a) experimentation and iteration, b) testing and debugging, c) reuse and reinvention, d) abstraction and modularization (from Harvard Graduate School in Education) in which the indicators for each stage of execution mentioned above were established.

During the data collection process, the survey technique and the questionnaire instrument were applied first for diagnostic evaluation purposes, then the observation technique and the observation guide instrument, with achievement levels: low, medium, high introduced in a rubric to assess the skills specified by the experts.

The workshops, it was carried out in person in a standard classroom (without elements commonly found in a laboratory) where the teacher presents the contents of the class and the components.

Subsequently, the questions are asked immediately after each topic is explained, once more than 60% of the participants answer the questions correctly, the next topic is evolved. Once the explanations and presentations were concluded, the process of assembly and commissioning of the didactic prototype was demonstrated.

The last part established is the commissioning of the prototype. The main functions and method of use of the Graphical User Interface or GUI are demonstrated, it ends with the comparison of the data acquired by the integrated sensors of the prototype with local measurement equipment (a thermometer for example) and the class is finished with a request for feedback from each participant.

In addition, the statistical design used the Statistical Package for Social Sciences (SPSS) program, based on primary data, for the processing of quantitative data, presenting the main results through statistical graphs.

The indicators used in the observation, through the rubric, were the following:

Experimentation and Iteration Criteria

- Create a CubeSat project step by step
- Try things on the go
- Make reviews based on what happens

- Try different ways of doing things or try new things.

Testing and Debugging Criteria

- See what happens when you run your CubeSat project
- Describe what works differently than what you want
- Review programs to investigate the cause of a problem
- Make changes and tests to see what happens
- Consider other ways to solve the problem

Criteria for Reuse and Reinvention

- Find ideas and inspiration by trying out other reading projects and programs
- Select a piece from another project and add it for your project
- Modify an existing project to improve or extend it
- Give credit to others whose work you've used as a starting point or inspired you

Abstraction and Modularization Criteria

- Decide what objects are needed in your project and where they should go
- Decide what programs are needed in your project and what they should do
- Organize programs in a way that makes sense to them and others.

3. Results and Discussion

Below are the results obtained during the CubeSat teaching hands-on class. Figure 1 showed the utilized CubeSat prototype in this assessment.

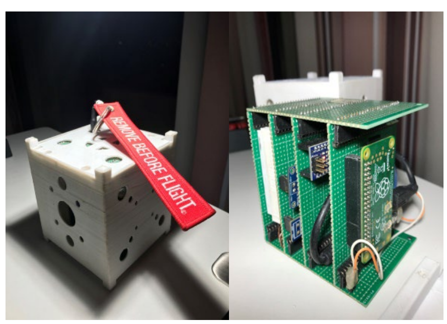

Figure 1: CubeSat prototype utilized in this hands-on class.

As seen in the Figure 2 from Experimentation and Iteration, 100% concluded that they are moderately able to "Build a project with CubeSat step by step. Regarding the following indicator, 22% concluded that they can moderately "try things on the fly" and 77% have a high degree.

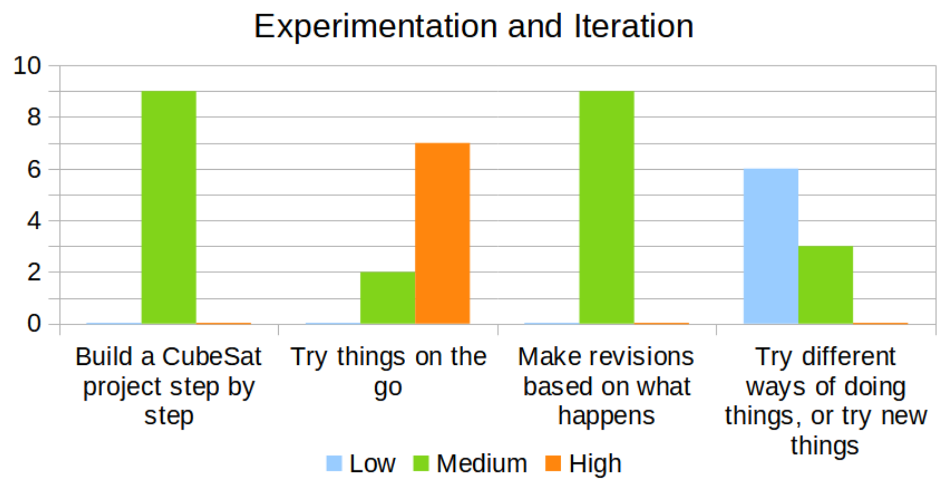

Figure 2: Results from Experimentation and Iteration criteria.

100% concluded that they can moderately "make reviews based on what happens. One group of 66% concluded that they can hardly "Try different ways of doing things or try new things" and 33% do so moderately.

In this sense, experimentation and iteration, it can be concluded that it has shown that all students find it relatively easy to build and review a project, however, a small group finds it a little difficult to make revisions, as well as try different ways of doing things, this could be deepened looking for factors that are present in the ways students learn and traditional methodologies that do not include inquiry or research.Figure 3: Results from Testing and Debugging criteria.

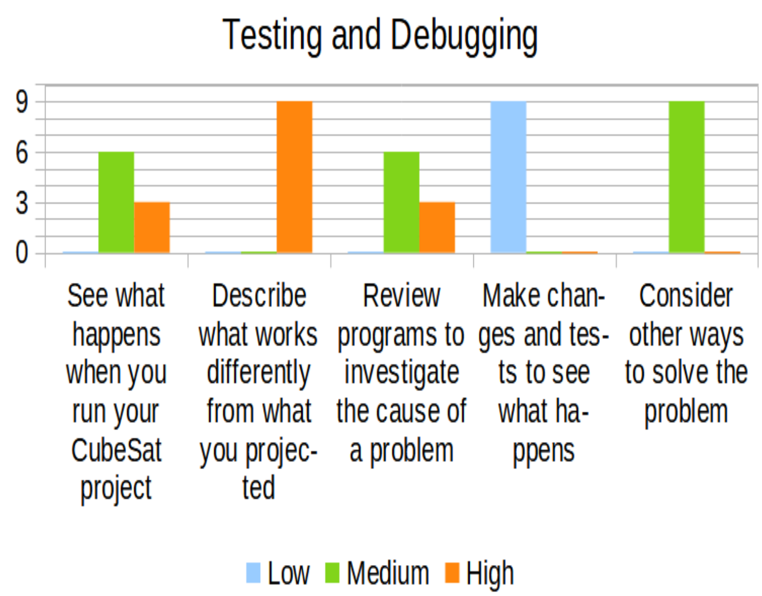

Figure 3 testing and debugging

Figure 3 shows test and debug results where a group of 66% concluded that they moderately achieved "Observe what happens when they run their CubeSat project" and the other 33% have a high rating. 100% concluded that they have a high rating to "Describe what works differently than what they projected."

On the other hand, 66% concluded that they moderately manage to "Review programs to investigate the cause of a problem" and the other 33% have a high rating, and 100% concluded that they can do little "make changes and tests to see what happens."

100% concluded that they moderately "consider other ways to solve the problem."

With regard to reuse and reinvention criteria, students are highly able to modify the existing challenge, but not little able to appropriate the project, give credit to other people and generate new ideas. This is shown in Figure 4. Implementing methodologies such as promoting creative thinking could help improve these indicators.

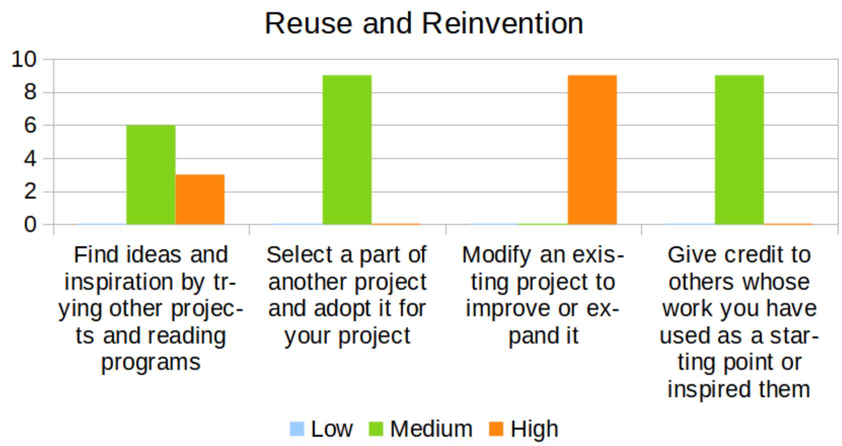

Figure 4: Results from Reuse and Reinvention criteria.

Regarding the criteria of reuse and reinvention, finding ideas and inspiration by trying other projects and reading programs was 66% medium and 33% high. On the other hand, 100% moderately concluded "They select a part of another project and adopt it for their project".

Likewise, 100% concluded that they have a high degree of "Modifying an existing project to improve or expand it" and 100% moderately concluded "They give credit to other people whose work they have used as a starting point or have inspired them".

In the criterion on reuse and reinvention, most of the indicators demonstrated an average ability to find ideas and inspiration in other projects, in the selection of another project, and adopt it for their project and give credit to others whose work they have used; meanwhile, the high degree was observed in the modification of a project if they exist to improve or expand it. (Figure 4)

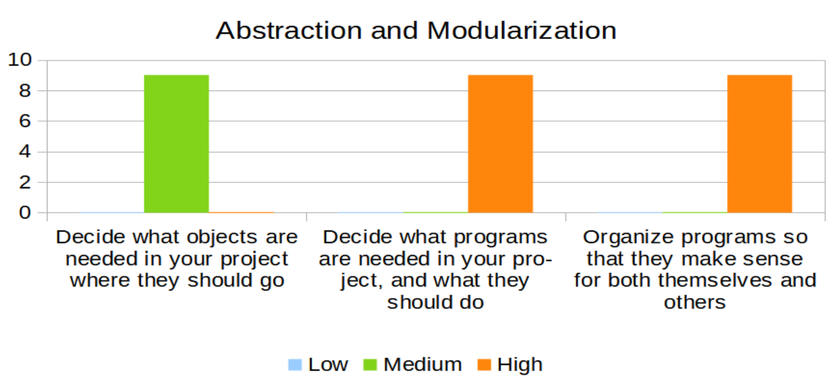

Figure 5: Results from Abstraction and Modularization criteria.

In this Figure 5 on the process of abstraction and modularization, 100% moderately concluded "They decide what objects are needed in their project and when they should go." In addition, 100% concluded that they have a high degree to "decide what programs are needed in their project and what they should do." In the same vein, 100% concluded that they have a high degree to "Organize programs so that they make sense both for themselves and for others."

In the latter criterion, it was possible to observe a better understanding and a high level in the decision of which programs are needed in their project and what they should improve, in addition to the organization of the programs so that they make sense for them and others; and in an intermediate degree when deciding what objects, they need in their projects and where they should go.

Measurement of the usability of the GUI created to interact with the CubeSats module and electronic measuring devices.

According to ISO 25010, the usefulness of the software product is its ability to be understood, learned, used and become attractive to the user when used under certain conditions.

In this sense, a brief questionnaire was applied to measure this capacity in reference to the Graphical User Interface (GUI) created to interact with the CubeSats module.

The premise that the student "operates from a friendly graphical user interface" was carried out by applying a 6-point Likert-type questionnaire (0, Nothing; 1, Little; 2, Something-going; 3, Quite; 4, Much; 5, Much). 9 (nine) participated in the sample voluntarily after a call made by the teacher in charge of the experimental class.

The following results were obtained: 11.1% said the GUI was not understandable and 88.9% said it was understandable. Regarding the ability to be learned, used and attractive to the user, 100% of the participants agreed that the GUI had such capabilities.

4. Conclusion

With this work, it has been possible to conclude that students, when introducing a challenge in the classroom, with a prototype of a didactic module such as CubeSat, are able to develop skills to much or less extent when it is intended to focus on STEAM areas. It must be combined with methodologies that promote active participation.

In this same context, when testing and debugging the students showed that they are highly able to describe the challenge, but a weak ability to observe, review, look for other ways to solve the challenge was observed. This could be because it is necessary to change the focus of how to teach STEAM and use innovative methodologies that encourage problem-solving thinking.

In summary, all the students concluded that it was more satisfying for them to develop abstraction and modularization, which means that it was not difficult for them to make decisions and know how to self-organize.

In short, the teacher must be prepared to serve as a guide in the process and, as such, he/she must handle the methodology necessary to succeed in the implementation of didactic modules in the classroom. The repetition of the experiment addresses in greater depth the combination of innovative teaching methodologies that develop problem-solving thinking skills in areas yet to be studied.

A suggestion for the improvement of the understanding and motivating of the students on the points not achieved is the incorporation of various methodologies of problem-solving, as well as the promotion of the participation of the students in the didactic strategy and the active feedback in the process.

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Biographies

Derlis Ortiz Coronel, Professor at the National University of Asunción. Teacher of Guaraní Language and Culture, Teacher of Basic School Education, Bachelor of Science in Education, Master in Curriculum (Chile), Specialist in Scientific Research, Specialist in Teaching Methodology and Training Engineering (France), Doctor of Science in Education (Paraguay). He is a founding member of the NGO Jekupyty Moheñoiha, Consultant in the curriculum of Indigenous Peoples, Projector in socio-community activities, Academic Director of the Teacher Training Institute - IDT and Coordinator of the Analysis and Research Center of the FCE/UNA - Caaguazú. He has collaborated with the UNLP (Argentina) research team on linguistic issues.

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Cristhian Coronel worked as a teaching assistant on Computer-Aided Engineering (CAE) until receiving the degree of Electromechanical Engineer at the Nihon Gakko University (UNG) in Fernando de la Mora, Paraguay, presenting as final research work a prototype of Low-cost didactic CubeSat, using data acquisition and monitoring systems, an area in which he currently stands out in his work at the Technical Support Service for Biomedical Equipment of the Social Security Institute (IPS). His work on the analysis of an aluminum-sheet-based structure folded to form a lightweight CubeSat structure was presented at the 2nd IAA Latin American Symposium on Small Satellites (2 IAALASSS) in Buenos Aires, Argentina. Next, he presented his work "Building 1U CubeSat as a Tool to Promote Project-Based Learning in Paraguay, a Case Study" at the 2021 ASEE Virtual Annual Conference Content Access.

Hector Velazquez is a Senior Student in Mechatronic Engineering at the Facultad de Ingenieria de la Universidad Nacional de Asuncion in Paraguay, currently working as an intern at the Agencia Espacial del Paraguay, also he is an entreprenuer, co-founder of KorapyTech, startup focused on data collection and analysis for livestock production in Paraguay.

Jorge Kurita attended Universidad Nacional de Asuncion in Paraguay, where he got his BS in Electromechanical Engineering. After graduation, he spent some time in academia working as faculty. During this tenure, he taught courses on heat transfer, fluid mechanics, and physics. In 2004 Dr. Kurita was granted the Fulbright scholarship to attend a graduate program on Mechanical Engineering at Michigan Technological University. He has finished his MS and then continued with a doctorate program. NASA and the NSF funded his doctorate research. Dr. Kurita's contribution to his field was well-published in several papers from high-impact journals. From 2011 Dr. Kurita worked as a development engineer II in the competitive automotive industry, Filtran LLC, located in Des Plaines, Illinois. As an experimental researcher, his experience helped Filtran develop special testing techniques never implemented before on filtration systems. In addition, Dr. Kurita worked in the CAE group, contributing to developing simulation techniques to help build state-of-the-art filtration systems. Dr. Kurita participated in developing OEM filters; some of them obtained awards from Jatco and GM. From 2016 Dr. Kurita is back to his alma mater as an assistant professor in Universidad Nacional de Asuncion. Later the same year, he is appointed to lead the research department of the School of Engineering. In 2017 he was appointed to be the Mechanical Engineering Department head at Universidad Nacional de Asuncion. In August of the same year, Dr. Kurita is awarded the “Distinguished Citizen by the City Council of Asunción” for his contributions to education in Paraguay’s space sector. And in December of the same year, he was mentioned as “Outstanding Protagonist of 2017” by the newspaper Ultima Hora.