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Tech Lunar Toilet: A STEM Project with High School Students

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ABSTRACT

We performed an innovative STEM outreach project. High school students from the Colombian robotics' designed a prototype of a Lunar Loo named Tech Lunar Toilet (TLT) that was part of the international HeroX-NASA Challenge. These experiences were possible thanks to a wonderful network of collaboration. As a result of this program, the students that participated were able to cultivate their curiosity, strengthen their scientific skills and increase their interest in pursuing careers in STEM fields. Simultaneously, they were able to contrast visual and instrumental data obtained from the robotics and new technologies that can be performed in the microgravity environments for future space explorations. The efficient TLT suction system will guarantee proper operation in both microgravity and lunar gravity. Most of the structure can be built in a 3D printer using PLA as a raw material. This polymer made from renewable resources with mechanical properties comparable to the petroleum-based ones will allow reducing the weight of the structure. We recognized that our project-based education is a powerful engine for development. We share our methodology for the construction of our TLT that can be used in microgravity. We also show the progression and impact of this innovative project of scientific dissemination.

Keywords: democratization of outer space, STEM education, science, outreach, education, democratization of science, social-scientific, lunar toilet, robotics

INTRODUCTION

Increased community participation and understanding of the importance of contributions from science, technology, engineering, and mathematics (STEM) are social change drivers (Kendall-Taylor, 2017). Because STEM education has the potential to strengthen a country's economy, educational programs with an emphasis on science, mathematics, technology, and engineering have become a global priority (Quigley and Herro, 2016; Kelley and Knowles, 2016). Several countries have been implementing strategies in the teaching of STEM careers, generating technologically advanced societies. Such is the case of South Korea, Germany, Singapore, among others. Since the provision of educational services and programs aimed at the democratization and appropriation of scientific knowledge requires large investments for implementing STEM educational strategies at the national level, the integration of such strategies into the educational systems of low- and middle-income countries has proven to be very difficult. While the challenges of implementing STEM education strategies vary from country to country, lack of resources, resistance to curriculum change, and social inequality are prevalent issues in countries with high poverty rates and poor infrastructure (Savage, 2018).

The conditions of outer space require appropriate technology and tools to deal with the consequences of microgravity, reduced water supply and restricted diet, among others, on the human body during medium and long term space missions. The development of human metabolic debris collection for spacecraft presents some important challenges in microgravity conditions. The capture and separation of feces and urine from crew members and the reduction of water use are examples of things to consider in this technology. In this context, we present the *Tech Lunar Loo*, which is a pre-treatment and treatment system for the use and final disposal of organic waste under zero and microgravity conditions. In this case, the safe, reliable and economic way of integrating the Environmental Control and Life Support System (EC-LSS) and the systems used in the International Space Station (ISS), allows us to have a novel configuration in addition to new elements to the systems designed previously, since it implements the principle of modularity and does not compromise the operation of other components, optimizing the process at a low cost. Our system is composed of three stages for the management of organic liquid, solid and solid/liquid waste. In addition, it has physical and chemical treatment phases (filtration, disinfection, dehydration, and stabilization). Typically, there are different methods to treat urine, feces, vomit, diarrhea and menstruation both on Earth and in outer space. Traditional methods of separating liquid and solid waste are proposed in this article.

WHY COLOMBIA?

Throughout history, Colombia has suffered from a diverse range of socio-economic issues that arise from widespread corruption, drug trafficking, and an ongoing internal conflict that has severely affected rural communities for more than six decades. However, the Colombian government signed a peace agreement with one of the many armed groups that participated in the armed conflict (LeGrand et al., 2017). Other armed groups continue to make a war that affects farmers, rural communities and are also causing many deaths of social leaders throughout the country. Research reveals that increased community participation and understanding of the importance of STEM fields' contributions are drivers of social change (Kendall-Taylor, 2017). Yet, the scientific advancement in countries like Colombia requires large investments in infrastructure and a diverse offer of educational services and programs aimed at the democratization and appropriation of scientific knowledge. In this sense, the articulation between different economic and academic sectors with international cooperation is fundamental for the country's scientific advancement.

As scientists and Colombian citizens, our group is committed to strengthening STEM education in Colombia. To achieve this goal, we collaborated with public and private entities to work with one of the population groups with the most significant social transformation potential: middle and high school students. To do so, we brought together highly recognized international scientific actors to collaborate in an *avant-garde* scientific experience, and at the same time, gain a better understanding of the wide diversity of social contexts in the country.

OUR METHODOLOGICAL APPROACH

The latest technology developments have become space investigation, a milestone that was only available and sponsored by the wealthiest governments. It is expanding, and now, it is an initiative funded by private organizations (Smith et al. 2012; Bugga and Brandon, 2020; Ackerman, 2020). The new generations should equally have access and encourage them to enjoy STEM fields worldwide. For that, it is compulsory to promote STEM initiatives. Educational efforts to spread STEM education, such as Cubes in Space, drive initiatives to encourage STEM projects for underrepresented and low-income groups that originally these scientific contributions due to the lack of infrastructure and mechanisms have not been relevant. In our project with MyRoboTech S.A.S, we considered these restraints and set up the development of this plan. MyRoboTech S.A.S is an educational institution that supports students in science, electronics, mechatronics, and robotics drives in enhancing self-thinking, manual skills, creativity, and management in solving problems combining science and innovation.

In our project, the students are given a space where they have a greater approach to the development of technology, being a doer and not just a consumer, with the purpose of making them inventors, creators, innovators and entrepreneurs. The ideation phase of the project begins with the proposal by HeroX-NASA. The ideation consisted of presenting a prototype of a toilet that adapts to lunar gravity and microgravity conditions. Through Newtonian mechanics and robotics classes, the main bases were given to understand the effects of microgravity. The aspects that would involve using liquids and other essential factors to take into account in space were investigated through videos of astronauts' experiences developed in the International Space Station (ISS). After

Figure 1. Flow chart of the methodological process

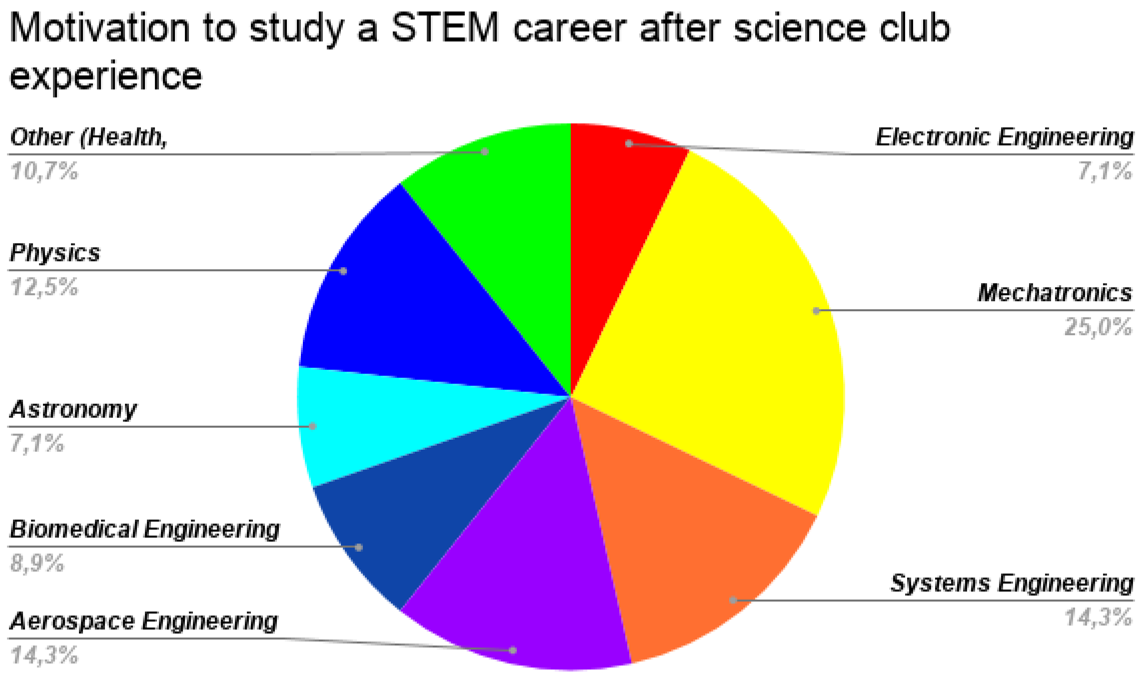

Figure 2. Pie chart of the future STEM careers of MyRoboTech's children choice

understanding the essential characteristics, a brainstorming session was developed. The children made the respective presentations to our working group, which was resolved to question how they could develop the best toilet on the moon? We took the best ideas with a group of scientists and mentioned them to implement a preliminary design. Here, we divided the working group of children into three teams. According to their expertise in mechanical, electrical/electronic, and programming. Each of them had the feedback according to the process to reach a design with modular features, mechanical development easy to use and low weight, so it was finally raised in the mechanical design development in 3D with PLA filament, easy installation. All measures were acceptable for the project and programming to implement the Internet of Things (IoT). Finally, each of the design proposals was integrated and adapted to the final design. **Figure 1** shows a flow chart to illustrate the process.

Finally, we wanted to know about the motivation and future application in STEM careers, given the fact that 100% of MyRoboTech students will intend to study STEM careers. In this case, we wanted to know to which careers they would apply and how these projects oriented them to decide on which topic. It is worth noting that there is an extension of these results in Supporting Information, also giving a close look at the percentage of girls in STEM. **Figure 2** shows a percentage of the STEM careers that MyRoboTech students will apply when they finish their school studies.

MAKING THE TECH LUNAR LOO

At this toilet design (**Figure 3**), the astronaut ergonomy is considered. The best position of his body during the toilet usage, considering both men and women. Once the astronaut takes a seat, the device turns on.

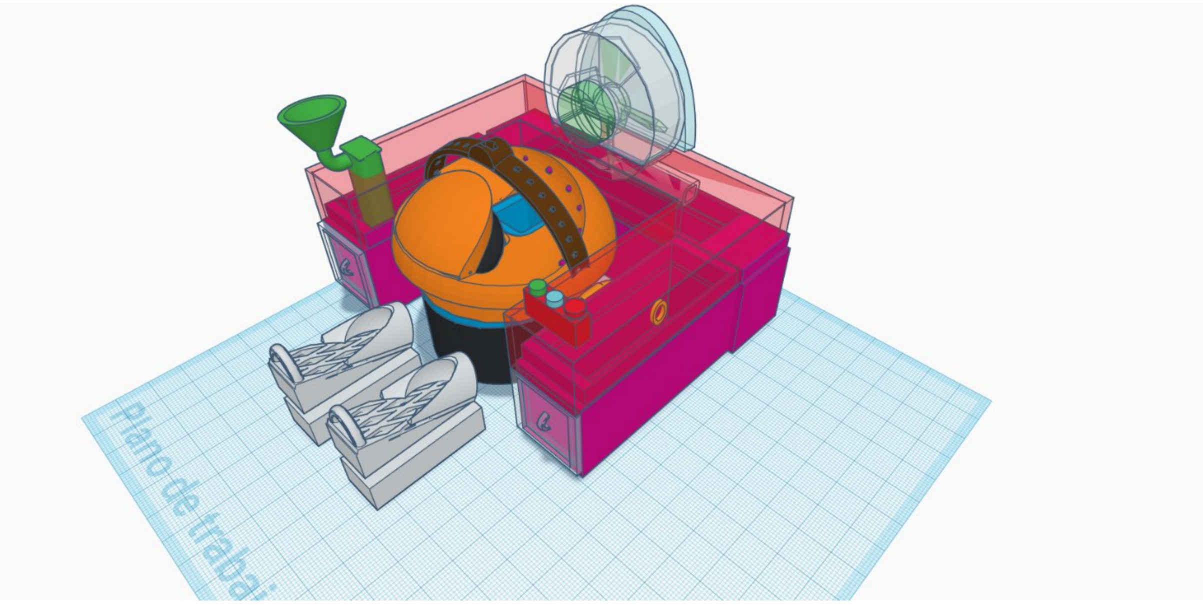

Figure 3. Final mechanical design of the Tech Lunar Loo

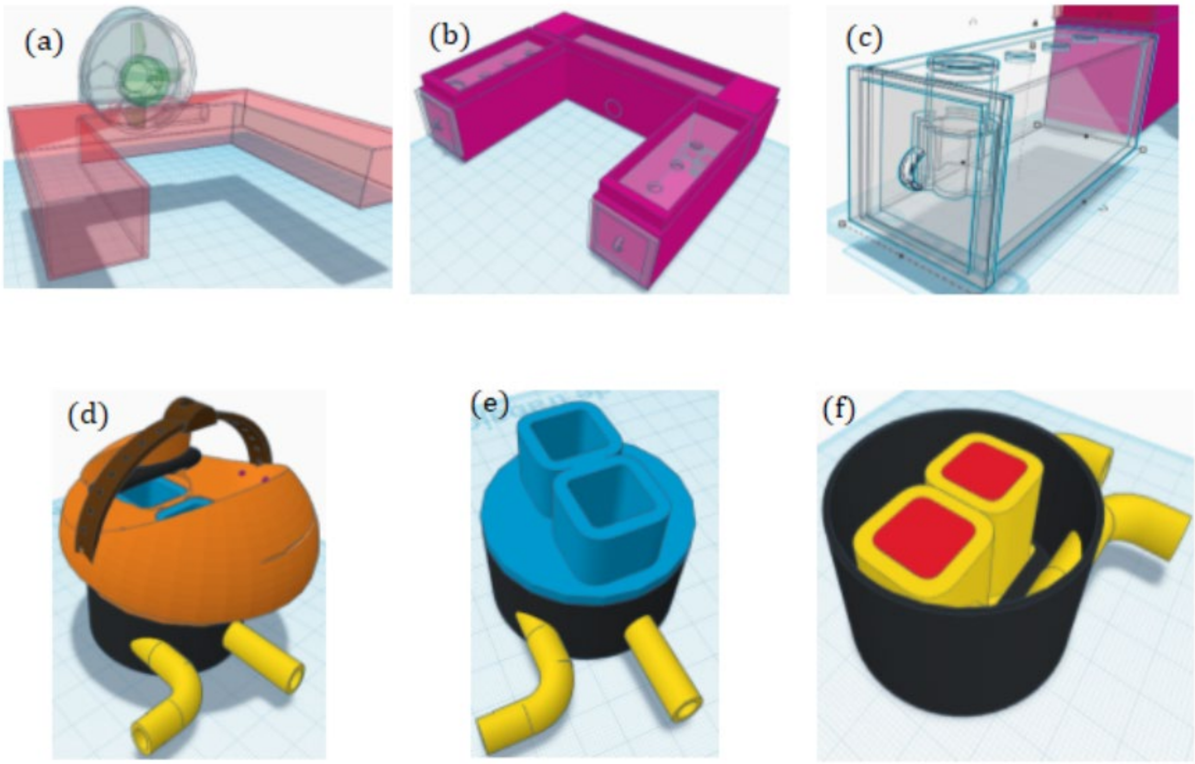

Figure 4. Tech Lunar Loo with easy to install modular system: (a) upper vacuum module, (b) lower vacuum module, (c) storage compartment, (d) chair with strap and genital locking system, (e) valve connection duct, and (f) liquid and solid valve system

The suction system is then activated when the lower sluice detects a pressure differential in any of the two cavities and allows the passage of the waste to the bag subdued into negative pressurization. This system avoids unpleasant odors in the toilet cabin. The negatively pressurized cabin is easily disassembled to fix any damage. Inside it is sealed with a material covering the 3D impression's porosity until 10 PSI, using a plastic band on the lower part; this improves the equipment sealing. The toilet bowl has an inclination of 15° for the better ergonomic position of the astronaut. The system is sealed and perfectly aligned, which makes the piece replacement. According to the change of pressure on any of the three entry cavities, the suction system has two servomotors to open or close the cavity gate. In the case of a positive pressure change, the gate is open. As the gate is closed in the case of negative pressure change, the waste is carried to the respective bag. Something important to highlight in this toilet design was the ease given to the crew to assemble and disassemble the complete assembly (**Figure 4**).

On the other hand, we considered that each part is manufactured on a 3D printer with polylactic acid (PLA). PLA is a biodegradable thermoplastic made from renewable resources such as corn starch or sugar cane. Making easy disposal and returning to the natural life cycle.

The toilet has a UVC ray-based disinfection process, which is performed when the toilet is not in use, and it requires at least 15 minutes for cleaning. The astronauts can activate manually the suction system located to the right side for throwing up. Once used, the astronaut must change the deposit funnel and throw it in the fecal matter hole. On the left side, the astronaut can find wet towels to clean any part of their body. Security is essential for the crew. Thus, the Tech Lunar loo has a Bluetooth system of communication and a Door Color Lights Code, which activates the emergency system if anyone in the toilet is at risk and controls the temperature-humidity in the bath. The electronic system (Supporting Information) was designed with the HeroX contest's specifications and the students' ideas with the bases provided by MyRoboTech S.A.S Academy. Our ideas included the internet of things (IoT) bases for real-time communications between the main cabin's electronic systems with the toilet, which included the voltage regulation system (a future work would include principles of self-driving labs as (Langner et al., 2020)). We also included humidity sensors, temperature in circuits and cabin, passive infrared presence sensors (PIR), external, internal lighting system, differential pressure sensor in the two ducts and proportional valve closure by servomotors, button panel for manual-automatic use, vacuum system with the blower motor, servomotors with mechanical pressure sensor for closure system in genitals and continuous disinfection system by UVC rays, all controlled by an Arduino UNO which will help us with the control strategy and sending data via Bluetooth.

CONCLUSIONS

Our results show that cutting-edge research can motivate young people in society and produce extraordinary results. By carefully preparing the experiments, we have proven that our toilet named Tech Lunar Loo that we proposed employed robotics, programmation.

Our team has been supported by several active academics interested in science and outer space democratization as an engine for social and scientific change. Our project gained momentum thanks to their contribution and allowed the participation of new actors who intensified our methodology's replication and continuous implementation. Thus, our project arises from a cooperative approach that develops science, technology, and mathematics education in a small city in Colombia, and contributes to the strengthening of scientific culture. We hope that shortly, the students who benefited from this type of program can help increase our planet's sustainable development.

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