Cunning: From play to wit, a STEM science club for technological and social entrepreneurship

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Abstract - **The lack of –Science, Technology, Engineering and Math– STEM skills in the Colombian students, has stopped the development of abilities required in the twenty one century. The kids and young people do not consider STEM careers as a successful and viable life project, because of the economy background. That is the reason why scientist, technology entrepreneurs and non-profit organizations seek a social transformation by expanding the access to high quality STEM education, through programs that include projects in order to find problem-based solutions, develop technical and cognitive skills and real experiences with scientific and technological material, incorporating 80% practical and 20% theoretical classes and the interaction between high quality scientist and a rural community, in order to share knowledge. This investigation shows the work made by a Scientist team and a group of kids and young people of the municipality of Túrreques, Nariño, supported by the German technology Fischertehnik, the Technical Academy of SENA and "Clubes de Ciencia Colombia", that allowed these kids to increase their self-confidence by using this technology and their logical reasoning as an intention of contributing to the realization of a better future in Colombia. This work is opened to future research in the field of education and science.**

Index Terms - STEM Education, Science Knowledge share, Technology Education, Community work.

INTRODUCTION

According to the last study of the Colombian Republic, only one out of every three Colombian scientist who have studied abroad return to the country, and they report there is no conditions to continue their scientific work. The brain drain in the country is rising [1]. In addition, Colombia has the lowest score in PISA records for solving problems skills, which shows the lack of –Science, Technology, Engineering and Math– STEM skills in the students. These are required abilities for the future jobs in the twenty first century [2]-[3], and only 1.6% of students in Colombia choose STEM careers [4]. This scenario is totally disconnected to the agenda 2030 of the millennium sustainable development goals, and the competitiveness advantage that represents involve more people into STEM careers [5]. The root of this problem in Colombia regards to the mindset about scientific careers and the stereotype of a scientist: the conception of an old white man, crazy hair and white coat enclosed in a lab. Thus, kids and young people do not consider STEM careers as a successful and viable life project.

Clubes De Ciencia Colombia – CdC Colombia [6], is a non-profit organization, part of the Latin American initiative of Clubes de Ciencia Latinoamerica [7] that "sparks a social transformation by expanding access to high quality STEM education and collaborative networks" in six countries: Mexico, Colombia, Peru, Bolivia, Paraguay and Brazil. This STEM program brings together scientists and Ph.D students of the best universities around the world, local scientists and children to develop problem-based courses in STEM topics, during one week in rural communities.

The Club offers free intensive one-week courses in STEM fields for Children and Young Colombians who are secondary school or first years of undergraduate. The participants of the clubs work on short projects focused on develop technical and cognitive skills on issues of national and global relevance (e.g., science of health, energy and engineering, nanotechnology, etc.). The operation line is funded by the government of Colombia through a grant from the national department of science and technology of Colombia – Colciencias [8], the national service of technical learning – SENA [9] and others private institutions for funding sources.

There is a need for an increase in the number of students entering fields of science and technology, and a way of make that happen is to change priorities aligning the 21st century education into a globally competitive STEM education. A problem solving-based approach of education will allow children to achieve STEM skills at the same time subjects cover and ties a curriculum rather than being just an additional set of new standards [10].

The STEM approach of education, include having students who can identify an issue or challenge, conduct a research, plan a research question, think and design a solution, then test and evaluate it and finally communicate the results [11]. That is why, "Clubes de Ciencia Colombia", as an STEM methodology, regards to international standards for developing 21st century skills in Children and Young people. "Clubes de Ciencia" is a project-based learning and

hands-on experience that brings STEM skills throughout an intensive-short experience with scientists [12]. The pedagogical bases for "Clubes de Ciencia" program, not just focused on conducting research, but on utilizing research-based strategies for developing skilled children and young people. This project provides a hands-on experience with instructional materials, planned 80% practical and 20% theoretical classes, tools for impact assessment for both: scientists as instructors and children as participants of the clubs. "Clubes de Ciencia", fits not in normal scheduled classes but a summer intensive short course, with the intention of inspire and motivate children into future STEM careers.

According to OECD report, some recommendations have appeared in the STEM education field in Colombia, focused on the necessity of a math and science improvement [4]. However children and young people in rural zones are still not engaged with STEM learning fields, and one way to tackle this problem is to inspiring them throughout the Club, which has a huge impact on STEM education, especially when its focus group are teenagers and 12 aged children. Align with Colombian report from OCDE commission, this is an appropriate strategy which brings mid and long-term results on quality and equity of scientific education for children and youths in rural areas of the country. Supporting this, for instance almost 30% of the total population in Colombia are aged less than 15 years old [4], and "Clubes de ciencia" has worked with this age rate from 2015 to 2018 impacting more than 5,500 kids.

Furthermore, OECD reports a limited career guidance and a lack of linkages between educational contents and the work world, then students choices and the prospects of the most disadvantaged population, like rural students, will not be aligned with an increment of future STEM professionals [4]- [13]. That is why "Clubes de Ciencia Colombia" impacts on short-term STEM guide using role models and real scientists working directly with children.

CONTEXTUALIZATION, MOTIVATION AND CONVERGENCE

"Colombia needs education first and foremost. The context, the ability to understand what it means and what is the use of what we are studying and understanding and memorizing, that is the most important thing. Helping people to be as smart as possible, that's education." [14] Thus, in the first place, the personal interest in education appears, which is a particular topic that as time goes by allows interaction with other people who share the same concern. In this vein below, are some figures that describe the context of education in Colombia:

According to the National Administrative Department of Statistics (DANE), by 2017, 10,020,294 nationwide students were enrolled in schools out of a population of approximately forty-five million [15], representing a total variation of -0.3% with respect to 2016 [16]. Likewise, the National Education Ministry - MEN, through the National Information System for Higher Education - SNIES, reports that by 2017 1,934,546 people were enrolled in the different academic, technological or university professional programs offered by Higher Education Institutions - IES in the country [17]. For the same period, a total of 342,672 people was reported to have been graduated from the Colombian higher education system [18]. Table I consolidates a comparative of students enrolled in HEIs during 2017, differentiating the cases of students who decided an engineering training at technical and professional levels, with people who opted to explore other fields of knowledge. It also identifies trends in participation by gender and the obtaining of the degree corresponding to the studies carried out.

TABLE I
COMPARATIVE RECORD OF STUDENTS ENROLLED IN ENGINEERING PROGRAMS IN COLOMBIA FOR THE YEAR 2017

Field of knowledge	Gender (Female – Male)			
	Enrolled		Graduates	
Technology Level				
Engineering	**271,202**	80,284 190,918	43,025	13,073 29,952
Others	600,067	364,185 235,882	90,730	57,222 33,508
University Level				
Engineering	**230,207**	74,159 346,966	44,545	16,166 28,379
Others	833,070	506,253 326,817	164,372	106,203 58,169

According to the trends shown in Table I, 25.92% of people enrolled in higher education programs in Colombia began their studies in areas of engineering. In the same period, a similar percentage, 25.56% of the degrees were obtained by engineering students. It is worth mentioning that the empowerment of women in Colombian engineering requires special attention, since their participation in the development of national engineering constitutes a highly considerable opportunity evident in the following trend: By 2017, the percentage of inscriptions in technological level by women was 29.60%. In addition, the grades by that gender in the same period corresponds to 30.38%. Furthermore, the percentage of women enrolling at the university level was 32.21%, and the percentage of women's degrees in the same period was 36.29%. In fact, according to the argument illustrated in Table I, firstly, in other fields of knowledge the number of women enrolled in the different training programs offered by the IES predominates and secondly, although the levels of participation corresponding to the training and professionalization of persons in engineering in Colombia are reduced in comparison to the same in other fields of knowledge. It is considered relevant, pertinent and necessary to make a sustained effort to stimulate the vocation of young talents in engineering at an early stage. Therefore, the study of internal processes for the transformation of the profile of people enrolled in engineering programs until their studies culminates, the obtaining of a degree and their beginning in the professional work, is not the main objective of this article, but this topic is necessarily articulated and will be addressed in future studies. On the other hand, in the methodological development and the case study of this paper, is intend to

address the problems corresponding to the stimulation of interest in Science, technology, Engineering and Mathematics, in children who are currently studying the cycles of secondary and middle basic education in schools in Colombia. It is even intended to go a little further because of the integration of the STEM concepts approach and the technology-based and social-based entrepreneurship, establishes a clear and entertaining link between the profile of the college student and the future opportunities offered by contextualized engineering according to the conditions of his or her environment.

CHALLENGES

In the first place, the following purposes must be considered: "to promote technological innovation and excellence for the benefit of humanity." [19]. “To support the processes of: creation, development and integration of engineering, sharing and applying knowledge on technologies, electrical and information sciences in context, and naturally with the objective of promoting the social and economic development of humanity in Latin America and the Caribbean.” [20]. "To promote and disseminate cutting-edge scientific information and resources related to engineering education, providing opportunities for professional development in the academic community and the industrial sector.” [21]. In other words, a philosophical structure is generated and integrates all the topics previously mentioned, complemented with some other similar ideas as educational innovation which contemplates different aspects related to technology, didactics, pedagogy, processes and people. [22]. Ethical education by competencies, based on value ecology, sources, duties and ethical tensions as well as competencies in ethical education, namely Self-understanding, others understanding, context understanding and understanding the transcendent [23]. In that order of ideas, the main challenge is to develop the vocation to find new minds for science and engineering or the ability to leave a true legacy of quality in these fields of knowledge in an effective way. Then, in 2018 within the framework of the call for instructors, was formulated the science club "Cunning: From play to wit", whose main objective was "Stimulate interest in science and engineering of young students in the municipality of Túquerres in the department of Nariño [24] through the use of a STEM laboratory with Fischertechnik technology [25] for the development of creativity and innovation based on the technological and social entrepreneurship”. The formulation of the “Cunning” science club was evaluated by the organizing team of CdC Colombia 2018 and subsequently accepted to be held from 18 to 23 June 2018 at the facilities of the SENA Technical Academy in Túquerres [26] and was attended by 20 students from different schools in the area.

METHODOLOGY

The science club "Cunning: From play to wit" is an experience that generates interest in Science and Engineering in the young attendees, because in itself, this experience is something simple, allows participants to take advantage of their time learning from the context of situations, recognizing the facts and thinking about proposing solutions to the problems of their environment.
The word “"Cunning”, “Astucia” in Spanish, comes from the Latin "astucia", whose meaning refers to the dexterity or speed of intelligence. Intelligence, in turn, is closely related to the ability to understand, as well as the ability to solve problems through knowledge and experience. Thus, the methodological proposal for the execution of the science club "Cunning: From play to wit" considers the realization of different joint training activities between students and instructors, in which skills are developed in mechanics and spatial reasoning, principles of electronics, logical reasoning and principles of robotics, likewise, there is a permanent dialogue to stimulate imagination and creativity, at the service of innovation and entrepreneurship, around the needs of the local community. For all of the above, the use of STEM didactic technological tools was considered according to the German technological vector of Fischertechnik Company [27].

I. Stakeholders

- **Organizing Team of CdC Colombia:** Volunteer personnel in charge of the selection and realization management of the workshops proposed by the instructors in the different cities of the respective CdC Colombia edition [28].
- **Logistics equipment**: For CdC Colombia 2018 in charge of the company Arukay [29], in charge of the management of the correct realization processes of the workshops, as Inputs, the mobility of the instructors as well as the students, lodging, food, among others.
- **Instructors**: Each science club is made up of a team of two instructors, one international and one national. For this case, "Cunning: From play to wit" was in charge of Ph.D. Miguel A. Tovar and MSc. Juan P. Franco respectively.
- **The Students**: Boys and girls, mostly students from public schools in the municipality of Túquerres - Nariño, whose ages range from 13 to 17 years.
- **The community**: Represented by different people related to the educational process of the students, they accompany different activities to start and close the event, interacting with students, instructors, and organizers. Normally they are the parents of the students, the teachers of the schools, the directors of the related educational and governmental institutions and even, in this case, authorities such as the mayor of the municipality.
- **Sponsors**: Public and private institutions that have their own resources of physical and economic infrastructure to carry out the workshops. In this case, and in addition to those already mentioned in the introduction of the document, it is worth mentioning the Technical Academy SENA in Túquerres who had their classrooms and also the company Advanced Technology Didactic

[30], who provided all the Fischertechnik technology equipment for use in the workshops.

II. Methodological proposal of the science club "Cunning: From play to wit"

- **First day**: Scientific, Technological and Self-recognition Contextualization. Objective No.1: To identify the different opportunities for growth in the universe of Science, Technology, Engineering, and Mathematics, through the recognition of the different study alternatives, according to the characteristics of the personality of each individual. Activity No.1: Opening ceremony, the protocol for the initiation of science clubs. Simultaneous activity at National level. Estimated Time 120 minutes. Activity No.2: Beginning of the science club "Cunning", working rules and awareness workshop and integration to unify concepts related: Industry 4.0, the STEM methodological approach and learning through play. Estimated Time 120 minutes. Activity No.3: Lunch. Each day will last approximately 60 minutes as stipulated by the logistics team. Activity No.4: Introductory concepts to systemic thinking for children and young people. The individual Self-recognition through discovery and identification of typologies and personality traits. Estimated Time 120 minutes. Activity No.5: Closing of the day and Conclusions, relating the objective of the day with the Activities carried out. Each day will last approximately 30 minutes.
- **Second day**: Project-based learning and the STEM approach. Development of manual skills and follow-up of instructions. Objective No.2: To develop skills in building and driving remote-controlled vehicles with Bluetooth technology, by following steps in an instruction manual, according to the organization for teamwork. Activity No.6: Practical Workshop on Vehicle Assembly - Initial part, with the use of Fischertechnik advanced Trucks [31] and advanced BT Racing Set [32] models. Estimated Time 120 minutes. Activity No.7: Snack. Each day will last approximately 30 minutes as stipulated by the logistics team. Activity No.8: Practical Vehicle Assembly Workshop - Final Part. Estimated duration of 90 minutes. Activity No.9: Lunch. Activity No.10: Development of driving skills with built vehicles. Challenge of driving with obstacles in different environments of the Technical Academy. Estimated Time 120 minutes. Activity No.11: Closing of the day and Conclusions.
- **Third day**: Project-based learning and the STEM approach. Development of manual skills and logical reasoning. Objective No.3: To develop programming and construction skills for electromechanical models by following instructions according to the testing and use of sensors and actuators. Activity No.12: Conceptualization of the STEM methodological approach in perspective of the vision of the future of Science in Colombia. Fundamentals of electronics: Difference of Potential, Electric Current and Resistance. Estimated Time 120 minutes. Activity No.13: Snack. Activity No.14: Introduction to programming algorithms in the ROBOPro work environment [33]. A practical workshop for the testing of sensors and actuators - Initial part. Estimated Time 90 minutes. Activity No.15: Lunch. Activity No.16: Practical workshop for the testing of sensors and actuators - Final Part. Estimated Time 120 minutes. Activity No.17: Closing of the day and Conclusions.
- **Fourth day**: Project-based learning and the STEM approach and its integration with imagination, creativity, and innovation. Objective No.4: To identify opportunities for environmental improvement, to propose solutions involving the development of electromechanical prototypes integrating the use of different sensors and actuators available in the STEM laboratory. Activity No.18: Recognition of improvement opportunities and needs in the contextualized environment with agricultural applications, use of energy, impact on the community, among others. A practical workshop on creativity and innovation in context - Session 1 of 4. Estimated Time 120 minutes. Activity No.19: Snack. Activity No.20: Practical workshop on creativity and innovation in context - Session 2 of 4. Estimated Time 90 minutes. Activity No.21: Lunch. Activity No.22: Practical workshop on creativity and innovation in context - Session 3 of 4. Estimated Time 120 minutes. Activity No.23: Closing of the day and Conclusions.
- **Fifth day**: Project-based learning and the STEM approach and its integration with imagination, creativity, and innovation. Objective No.5: To implement solutions involving the development of electromechanical prototypes integrating the use of different sensors [34] and actuators [35] available in the STEM laboratory. Objective No.6: Identify the main characteristics of the proposed solutions to determine how innovative they can be. Activity No.24: Practical workshop on creativity and innovation in context - Session 4 of 4. Estimated Time 120 minutes. Activity No.25: Snack. Activity No.26: Poster design for the closing of the science club "Cunning". Estimated Time 90 minutes. Activity No.27: Lunch. Activity No.28: Closing of the day and Conclusions.
- **Sixth and last day**: Activity No.29: Closing Ceremony, Science Club Closure Protocol. Estimated Time 120 minutes.

CASE STUDY

- **Activity No.1:** All stakeholders were presented in the geodesic dome of the Technical Academy of Túquerres. The students attended wearing the uniform of their respective school, and the instructors were presented by the organizing committee of the event to the community. Likewise, the importance of the realization of science clubs for the development of vocations in

science and technology of the young talents of the municipality and the department was highlighted, thanking the support of the sponsoring institutions.

- **Activity No.2:** The students from 5 public schools of the municipality of Túquerres were presented, and for all, it was their first experience of study in the framework of science clubs. In the first minutes, the tendency of the young people was to stay together with their other schoolmates and did not participate voluntarily in the open dialogue so the instructors decided to establish a communication based on common experiences and characteristics, which allowed to inquire with a little more confidence about the interests and expectations of all children, because it was required to present the rules of work that essentially obeyed the collaboration, respect, and order.
- **Activity No.4:** Once the students were motivated and integrated, a presentation called "STEM Approach and Industry 4.0 as training strategies for future engineers in Colombia" was made. In this way, many new concepts were successfully presented to the young people, giving them a different perspective of how they relate and could relate themselves to the educational, economic and social systems, depending on the evolution of their knowledge and technical, technological and scientific skills. Due to technical problems with Internet connectivity, it was not possible to characterize the typologies and personality traits of each attendee, a situation that was overcome with a contingency plan related to the identification of personal and community values.
- **Activity No.5:** The students expressed their lack of knowledge of the after-school panorama at the academic level as well as at the labor or entrepreneurial level, so by identifying possible professional training opportunities exploring some field of knowledge in science and technology and relating this reflection to their interest, values and life expectancy they were enthusiastic to continue with the practical workshops.
- **Activity No. 6 and 8:** As the first rule to start the practices, the indication of working in an orderly manner with all the technological equipment assigned in their respective tables was given. The work groups assumed a collaborative attitude, identifying the abilities of each one of the members with the intention of potentiating them. A brief induction of using the parts and manuals contained in the fischertecnik vehicle kits was made, with which the instructors only had to give a little assistance to the students since most of the assembly work and device interconnections were successfully developed autonomously.
- **Activity No.10:** For this activity and with respect to the state of progress of the club, 4 of 6 work teams were able to finish assembling the models selected in the manuals on time, so they proceeded to develop driving skills through the use of remote control, on different surfaces, with the placement of obstacles and inclination tests. The two missing teams were able to finish their models about an hour later and joined their peers in the driving tests.
- **Activity No.11:** As the students themselves were modifying the conditions of the test drive terrain, they also began to modify the pre-defined vehicle models to gain speed and strength, thus beginning to take on more complicated challenges such as skidding or climbing steeper inclines with the same characteristics as engines and rechargeable batteries. It should be noted that the implementation of these improvements were ideas proposed by each of the working groups.
- **Activity No.12:** To begin the day, there was a small debate regarding the future of science and technology in Colombia, the empowerment of women in engineering and the importance of this scientific philosophy according to the values and vision of improving the quality of personal and community life. Then with the intention of illustrating and internalizing in the best possible way the theoretical concepts of Ohm's law, related to the physical magnitudes of a difference of potential, electric current and electric resistance. Then a small play was made, in which all the students participated with a previously defined role, some young people were atoms of a certain material, which could be: conductor, semiconductor or insulator. Others were free electrons that, depending on the conditions, could pass through the physical structure of the previously formed material, and others were the source of voltage or potential difference.
- **Activity No.14 and 16:** Having understood the physical magnitudes of Ohm's law, it was already possible to start using the different sensors and actuators available to the STEM laboratory, so we proceeded to perform an induction to the programming algorithms at level 1 of ROBOPro, then explained how to connect to the controller Robotics TXT [36] each of the sensors and actuators available. During the two work sessions, the students carried out several measurement tests combining several sensors and actuators at the same time to strengthen the idea and develop their skills. Precisely within the framework of this practice a working group especially interested in the resistive temperature sensor NTC, collaborated with colleagues from another science club "Energizing", who were making handmade heating devices which were heated to more than 100 ° C and at the time did not have a measuring instrument that allowed them to measure over that temperature range, so our students used a computer, a controller and the temperature sensor to make measurements digitally, thus contributing to solving the problem of their peers.
- **Activity No.17:** At this time and regarding the state of progress of the club, the students are quite motivated, interested in the subject by its practical organization and show their willingness to start working with their

own proposals contextualized thanks to the new knowledge acquired.

- **Activity No.18, 20, 22 and 24:** As a result of all the activities carried out so far, the students have been able to align the theme of the Club and the reality of its economic and social environment, so they have been clearly asked to consider the problems and needs of their community in which they can intervene with a proposal that involves the use of technology and that benefits in the best possible way all the people involved. Thus, after a dialogue between the instructors and each of the working groups, proposals were made related to Street lighting in urban areas, mobility in the countryside and animal safety on farms. From that moment on, the instructors limited themselves to giving assistance in the use of technological tools so that the students could develop their ideas in the scale models to be developed.
- **Activity No.26:** For the closing ceremony the students had to present the results of their work to all the stakeholders, For this, they had to design a poster completely on their own, in which they synthesized their experience; expressing there their understanding of the new concepts and the feelings of motivation for having been part of that STEM laboratory.
- **Activity No.29:** Once again all the stakeholders met in the geodesic dome of the Technical Academy. The students presented their functional models, explained their ideas and clearly expressed how they intended to solve the problems they identified in their environment, finally receiving recognition for their effort and dedication during the working week of science clubs. One of the most important moments of this activity for the students of "Cunning" was when the mayor of the municipality saw their proposals and asked them if they would know how to implement those solutions in real environments, to which they responded that they understood the process and the logical reasoning to do so.

RESULTS AND CONCLUSIONS

The Latin term Ingenium has three related senses: The natural disposition of the genius spirit, the capacity of the invention and the invented thing. The students attending the science club "Cunning" met the three conditions. Of course, this does not mean that they are either scientists or engineers, but allowed seeding interest in their lives for these fields of knowledge thanks to the early stimulation of vocation. This is evidenced by the results collected though a poll at the end of the course in which 83% of the students showed their increased desire to proceed their education into the Sience and Enggienering fields. These results are associated with the general growth trend of the national CdC program, which shows an increase in the number of clubs each year, 120 for the year 2018, as well as a better academic and logistical quality in each new experience.

With respect to learning through play, there are two things to highlight. The first one is related to the students, because for them to play with this type of technological tools means increase in self-confidence and to believe that they can achieve their goals. The second is with respect to generational change and the relationship between instructors and students, because for all of us to play together is to know that we are not different, to trust that we can share quality knowledge with the intention of contributing to the realization of a better future in Colombia.

Finally, the students were able to establish thought structures that allow them to logically reason a productive chain that relates their imagination, their creativity and the possible products and services with innovative potential for the benefit of the whole community. Particularly evidenced in the experiences of activities No.18, 20, 22 and 24. Nevertheless, it is very important that they continue to develop their ideas around this type of systemic thinking in their different environments, such as the school and the Technical Academy SENA at Túquerres.

FUTURE WORK

It was considered to develop the methodological proposal of the science club "Cunning" so it can be replicated in two levels: As a social projection by different institutions of higher education in Colombia and in the same framework of further national and international science clubs. Likewise, as a business plan that means extension courses in different universities to raise funds that allow financing the realization of more and better volunteers in this same subject. For more solid results beyond the assessment polls, it is possible to track the effects of the Astucia club in the particular students who took part on it and the upcoming versions.

ACKNOWLEDGMENT

We thank all the volunteers of Clubes de Ciencia, both the organizing team and the logistics team, because for their effort and perseverance this club was made a reality.

We also thank all the sponsors of the event, especially Mr. Hansotto Boecker, who has worked for a long time in the continuous improvement of the transfer of German technology to educational institutions in Colombia.

We thank all the instructors of the other five clubs in the municipality of Túquerres, because their dialogue and company has proved to be a great inspiration to continue with this type of project.

Finally, we thank all the people and institutions that have come together to support the growth of the initial idea of the "Cunning" science club, since they have believed in the future work and are contributing to its realization.

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