Construction of an amusement park using STEAM and LEGO education to participate in the science fair

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Abstract. This article explains details of the participation in the Science Fair that took place in the 2019 school year by some seventh-grade students from “Colegio Isidro Caballero Delgado”, Floridablanca, Colombia. This event is a space established by the institution, which takes place once a year to show different projects and experiments carried out by students from each of the school grades. The seventh-grade students for their participation took as their theme an Amusement Park; with this theme, they built different prototypes that resemble mechanical attractions using LEGO Education cards and applying STEAM. The aim is to explain different themes seen in the mathematics course during the year playfully and amusingly to the participating public through the operation of each of these prototypes and physics topics in its structure or operation. The structure of the document contains a first section, the introduction in which the context of the educational institution, the development of the science fair, and the use of LEGO Education cards for the 2019 version are addressed; a section II where the methodology and the applied strategy are detailed; in section III the results obtained are mentioned, and finally, in section IV the conclusions and possible recommendations are presented.

1. Introduction
Colegio Isidro Caballero Delgado is an official educational institution located in the municipality of Floridablanca, Santander, Colombia, with calendar A, with technical emphasis and of mixed character. The Institution is impacted by multiple factors and external aspects in different contexts that can interfere in the normal development of the academic process, from the social aspect we find the great influence of gangs in the sector, drug trafficking, theft, the families of the children have precarious economic situations, lack of employment of parents or constant changes of residences of their families. Factors such as lack of motivation to study in the students due to lack of economic support, loneliness, or abandonment by their families makes the institution generate different spaces with which the student is much more integrated.

Within the Institutional Educational Project (PEI) of the institution, we always want to offer an educational service with the best quality standards whose objective is to educate citizens integrally in a democratic environment, with enriching experiences and being sustainable individuals capable of generating spaces of transformation in a society facing the different challenges that arise in their local, regional and/or national environment [1–3]. In any academic process independent of the course it is common to find key issues that are difficult to explain, therefore it is necessary to identify strategies that lead the actors to have a good process, teachers to identify and incorporate new information technologies
[4,5], and relying on them to have more creative and innovative training spaces generating in students the interest to actively participate in the process, thus increasing their skills and competencies [6–9].

In the institution it is established to generate spaces to stimulate a comprehensive training and in which we can mention cultural meetings; entrepreneurship fairs; science fairs; vacation courses; extracurricular training groups; olympics of any subject such as physics and mathematics, i.e. inside or outside the classroom it is important to implement learning strategies [10], to strengthen innovation and creativity. The spaces contemplated in the institution help to strengthen its pedagogical model. In addition, from the academic directives, it is established that in each school year an institutional activity called Isidriana Week is carried out, which generally takes place in September, in which cultural activities are developed where plays, dances, reading space, poetry among others are presented; also sports competitions are held between different school grades in micro soccer, volleyball, and chess. An important point of this Isidriana week is the participation of the community where some students can present to the academic community some work done in some subjects such as physics, chemistry, mathematics, entrepreneurship, among others [11,12].

For the seventh-grade students to participate in the Isidriana week, which is developed in each of the sites, it was identified that their participation should be carried out using a STEAM methodology [13], and take advantage of the experience they were having in the construction of prototypes of real-life objects using LEGO tokens to present a theme together as a representation of the seventh grades. The article is the result of the development of the doctoral research. "Use of LEGO tokens to strengthen the learning of mathematics in the seventh grade" and of the students' interest in participating in the Isidriana week event that takes place in the institution, taking advantage of this experience and other related topics such as engineering, technology, the arts and especially the sciences through the assimilation of physics topics for their construction and operation, it is a unique experience since they identify and observe all these topics that are not they can easily represent them in a classroom in a theoretical and experimental way, adapting these themes to this school level. Of the total number of students in the five seventh grade groups of that school year in the institution, a total of 20 students worked for the participation in the Isidriana week, who were in charge of selecting the theme of participation, logistics, research to deepen aspects of the selected theme, among other aspects [14].

2. Methodology

In the school year of 2019 in the School, a doctoral research project is developed in which different learning [13], to strengthen the learning of mathematics in the seventh grade, during that time execution different activities are carried out applying instruments to see some topics contemplated for the course according to the Mathematics Area Plan [15], by the institution. With the realization of this experience, the students of the seventh-grade groups had the opportunity to handle the LEGO Education Kit 9686: Simple and Motorized Machines and kit of the Reference Fischer Technik L2 and D2 with which small constructions of prototypes of real-life objects that are in their environments such as models of cars, boats, swings, scales or any known [16–19]. For the participation of seventh grade students in the fair, it was established that the development and construction of a project would be used using the STEAM methodology [2,11], which helps to strengthen and promote the teaching-learning processes of students in an interdisciplinary way through different processes in which research, exploration and their interest lead to new concepts in different areas. As shown in Figure 1 the general planning of the STEAM methodology of the project.

The first step taken by the five seventh grade groups was to formally identify the theme of the project with which they wanted to participate in the respective Isidro Week, in first socialization, several themes emerged, among which were building a city, an amusement park, construction machines, animals, among others, leaving as finalists the construction of an amusement park and a city. In the end, the theme chosen for the seventh grade was the construction of an amusement park, which highlighted the interests of all the students.

After the selection of the topic, there was another component that was a little more complex to handle: which students were going to participate directly as representatives of the seventh grade in the Isidriana
week? How many students would be part of this group? What role would each one have in this group? with the experience of the doctoral project using LEGO tokens, from there the students with more construction skills and their academic growth were identified, also the other academic courses were monitored; the behavior and responsibility as part of a collaborative workgroup were also identified. For participation in the week, 20 students from the five seventh grade groups were selected of both genders and some children with special needs.

With the theme of the project and the groups already identified, it was necessary to establish the space and the working day that would not affect their academic process; the different roles that the students would have in the participation of the Isidriana fair (logistics, construction, research) and with this, six mechanical attractions were identified to prototype: roller coaster, Ferris wheel, giant squid, double swing, suspension bridge and three models of racing cars in order to search for information on their characteristics, structure, operation and other aspects to be able to explain them correctly in their participation in the fair.

As they are real objects of society that they do not know in depth the students began to read more about each of them finding different words and terms that they began to relate to topics seen in the mathematics course such as symmetries, reflections, rotations, translations, basic topics of statistics, related to rational and natural integers along with their representations in the cartesian plane and applications; however, they found information that they did not understand and that is important not only for the construction of the different prototypes but also to understand their structure and characteristics, such topics are gravity, inertia, acceleration, velocity, potential energy, friction, angles, among other terms that are necessary to build each attraction correctly.

For the execution of the amusement park project using the STEAM methodology, the following guidelines or conditions were contemplated:

a) The project is to visualize through a model and the construction of prototypes using Lego Education Kit and Fischer Technick Kit the simulation of an amusement park identifying the topics seen in mathematics and others such as physics that are required for presentation.

b) For the construction of the model, materials such as cardboard, wooden sticks, tempera, Kraft paper, Styrofoam, and others that may be required should be used.

c) Before prototyping each one of the mechanical attractions, it is necessary for the students to obtain the necessary information to understand each one of them and, together with the teachers, to deepen the terms found for the construction of each one of them, see Figure 2.

- The roller coaster will be built with turns, slopes and curves which will provide speed and acceleration to the marble that will be used and that is why the positions of each support must be well identified so that it works correctly. Therefore, it should be understood in a simple way that an angle is the part of a plane comprised in two straight lines taken from a point; it is mentioned that two different energies appear around the marble such as the kinetic energy that is related to the movement and the potential energy related to its highest position. Concepts such as inertia, gravity and height are also explained in a simple way.
For the Ferris wheel and the giant squid, besides having knowledge of kinetic and potential energy, it is necessary to know about the law of inertia, which consists of going from a state of rest to movement; the rotary or circular movement appears, which is the one originated on an axis, appearing in the objects the centrifugal force that is the force that takes them out of that rotation and the centripetal force that is the force that makes them remain bound to the center of the circle.

Figure 2. Preliminary construction of the prototypes.

With the suspension bridge that serves for an obstacle and to be able to get from one point to another, it is necessary to know what an anchor, the truss and the beams for the suspenders are. It is important to determine the distance in which the anchorages and the respective suspenders must be placed in order to support a certain weight.

For the double swing also appear the kinetic energy, the potential energy appears terms such as the pendulum movement that is to go from one side to another; knowing its structure can determine the weight and forces such as traction in its pillars and the chair suspenders; the bending in its beam and trusses; the torsion when the chair is rotating.

In the carriages, the translation movement is determined by using gears which transmit energy by changing the speed, direction, or direction of rotation. By using gears of different sizes, both the force and the speed can be increased or decreased.

Figure 3. Location of the prototypes in the designed model.

d) Then, for each one of the mechanical attractions, the "step by step construction instructions" are designed, which are understood as the indications that must be followed for an optimal construction according to the topic seen in mathematics and the topics required from other areas such as physics that are required for its correct operation, see Figure 3.

e) With the participation of the selected students, the construction of the different prototypes is achieved by making use of the step-by-step explanations given by the teachers regarding the concepts and terms related to each mechanical attraction and the relationship with the topics related to mathematics and very basic physics courses, to which the construction of the environment of the amusement park is made, that is to say the model and how the correct location of the same can be done.
f) On the day of the socialization there was a very good presentation of the project to the other colleagues of the school in which there was an excellent communication, explanation, and arguments with which they defended their ideas and hypotheses.

3. Results
Despite various unforeseen events, the seventh-grade students were able to develop and present a complete project called Amusement Park, see Figure 4. By using the STEAM methodology in the development of this amusement park, all the areas of this methodology such as science, technology, engineering, arts, and mathematics were involved, and with this, it is identified that all these areas are worked integrally through a good environment and with teaching-learning strategies to solve a complex problem. Students improved aspects such as innovation, design, inquiry, creativity to actively participate in the development and to be able to give their opinion on finding the best solution to the topic presented.

With the STEAM areas, it can be identified that through science students were able to learn how things work through research, technology using LEGO Education cards, engineering identifies some processes to make a good design for proper operation, and to know the processes for each of them. The execution of the project, although it was based on the STEAM and 4C Methodology, made use of different learning strategies to have an excellent learning environment, even though this activity was extracurricular. The use of learning strategies such as collaborative work [20], project-based learning [21], problem-based learning [22–26], gamification [27–29], game [30,31], are really important for the development of the competencies of each student [32]. The development of the project generated an innovative and investigative spirit in the students [33,34], since to build each of the prototypes they had to know in a general way some parts, their structure, and operation, such as, for example, the bearings that were used in several of the prototypes, what is an axis, support, among others, and how these objects could be related to the corresponding LEGO tokens.

In the construction phase, the students related the LEGO tiles used with pieces of the attractions in order to understand in a basic and general way their shapes and their movements in order to identify their place within the structure of the prototype and thereby discover their interaction to that the prototype is well assembled as well as that it works correctly.

Each and every one of the students related the operation of the different prototypes with some topics they have heard such as speed, height, gravity, spin, rotation, also learn, apply and calculate magnitudes and concepts such as motion, acceleration, force, work, power, energy, etc., and they apply fundamental principles such as Newton's laws, the law of conservation of the quantity of movement, the law of conservation of energy, rotation movements, pendular movement, kinetic and potential energies, all characteristic of each prototype, with this they always acquire a critical, analytical and argued attitude about the role of any object that is built and works in society. During the construction, many questions arose from the students regarding the relationship between the prototype's operation and real life, i.e., questions such as: does this work in a car? What happens if this is changed or if it does not exist? i.e., the development of scientific thinking is generated. With the socialization in the space of the science fair, it was identified that many of the students improved in their communication, built explanations and arguments with which they defended their ideas and hypotheses. In some moments through the LEGO
4C methodology, there were spaces for discussion and reflection in which the students actively participated, giving their opinions on the alternative solutions for the prototypes and on the best way to explain them at the science fair.

4. Conclusions
Following the context of the institution, the needs, and expectations of the teachers and students, this experience will lead to greater interaction with parents and the community, thus generating more visibility for the institution. With this experience, it is evident that the institution does not have adequate infrastructure to develop this type of activity, although the great capacity of response and support from the directives is identified so that it develops normally. This experience opens the possibility of participating with different products and projects carried out in the institution in similar events in the region where the school can participate with the representation of students and students.

This experience opens new perspectives in the objectives and scope of the science fairs, not only for individual activities but also for generating a formal articulation with the academic process that takes place in each of the school grades. With the participation of seventh-grade students in the respective Isidriana week, students face new challenges when using equipment contemplated in the new information technologies such as LEGO and Fischer Technik kits. By participating in this type of event, students improve their attitudes and aptitudes not only in academics but also in their integral formation, encouraging the responsibility they have in the execution of the project by being an active part of a group.

ICT for their learning is always a challenge for teachers because of the constant change that exists in them over time to ensure quality education. The students who participated in the project continued with their academic responsibility and therefore it is evident that participating in this type of events, the academic level did not decrease, but it was positive because it was interpreted in a better way some topics that are abstract in subjects such as mathematics. These types of activities open up new opportunities for the institution and its academic community in areas such as research, not only to participate in events such as science fairs but also to possibly present research projects to solve problems that affect them and thus be able to obtain resources for their execution. By incorporating the STEAM methodology, students feel more comfortable since they are an active part of their academic process and feel responsible for their learning according to the real context in which they live. LEGO Education allows the teacher to have a better environment in their classes with greater student participation and with the construction of the prototypes they assimilate more easily the contents and topics to be developed. With this type of methodology, the teacher is no longer just a teacher who transmits information but a person who identifies and characterizes, follows in a more individualized way to guide the evolution of student learning.

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