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Building, coding and programming 3D models via a visual programming environment

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Abstract This paper presents the findings of a study conducted in the state-funded Infant, Primary and Secondary School *Santísima Trinidad* in Salamanca. The main objectives of the research were, to evaluate the use of the visual programming environment, Lego Education WeDo, in natural science and to know the benefits of the use of this tool to teach abstract concepts, solve problems and motivate students. In order to achieve these objectives, we used the case study method since we focused on individuals who represented the phenomenon of our interest, and explored and investigated in depth the phenomenon in its natural context bounded by time and space. In the research were involved a teacher and fifty-two students of 4th grade of primary education. The study found that the project developed was effective to help students to achieve the learning objectives of the unit, and also to begin building, coding and programming 3D models. The research showed the teacher' fundamental role as a guide and students' active role as builders, programmers, or presenters. There were evidences of the possibilities offered to acquire the skills of critical thinking, creative thinking, problem solving, reflection, collaboration, communication, and time management. Due to the positive results obtained in this study, it is

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recommended to incorporate computational thinking in primary education and in core content areas since it is fundamental in the current society.

Keywords Computational thinking · Visual programming environment · Lego Education WeDo · Natural science · Primary education · Educational innovation

1 Introduction

In the present society, technology occupies a relevant position and has led to changes in different areas of our lives, and of course, in education and its curricula. Information and communication technology (ICT) plays an essential role in the way in which these curricula are implemented and taught (Pinto-Llorente et al. 2016a), and provides the resources that allow carrying out teaching–learning processes in a new way (Lamoyi 2012).

As Butler-Kisber (2013) points out, there is a movement in many countries to create curricula in subjects like science, technology, engineering and mathematics (STEM) that allows students to be prepared for the challenges of current and future society, and its demands. That is one of the reasons why teaching practice must change (Ghitis and Alba 2014). It is necessary to train students in what it is called digital language (Hafner et al. 2015) and in all the necessary digital skills to be part of the current digital world and to function efficiently in it. This includes the ability to do programming as a way to solve problems, and computational thinking (CT) as working paradigm (Llorens 2015).

CT is a term coined by Wing (2006: 33) to describe the way in which a computational scientist thinks. She defines it as “a fundamental skill for everyone, not just for computer scientists (…). Computational thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science”.

Cuny et al. (2010: 20) have defined CT as “the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent”.

The Royal Society (2012: 29) also adds “computational thinking is the process of recognising aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes.” It is a complex and high-level competence linked to abstract mathematical thinking, and pragmatic-engineering thinking, and applies to different aspects of daily life.

As García-Peñalvo (2016a, b, c, d) points out “computation thinking can be defined as the application of high level of abstraction and an algorithmic approach to solve any kind of problems” (2016a: vi).

It is not just a synonym of the ability to programme a computer since it requires a thinking that it is run in different levels of abstraction, and is independent of technological devices (Valverde et al. 2015). It is a problem-solving process in which the following characteristics can be emphasized: The way in which the problems are formulated allows us to use computers and other tools to solve them through algorithmic thinking. The data are organized and analysed in a logical way and are represented through abstractions. The possible solutions are analysed and implemented to know the most effective combination of steps and resources, and to generalize and transfer a specific problem solving process to other problems (ISTE 2011). CT includes abstract thinking, logical thinking, modelling thinking, and constructive thinking (Flores 2011; Liu and Wang 2010).

Several studies defend the idea that CT must be accessible to everybody and be learnt early and often (Lu and Fletcher 2009; Perkovic et al. 2010; Qualls and Sherrell 2010), and that it has the potential to be applied in a variety of disciplines apart from computer and information science and integrated into the basic curriculum (Bundy 2007; Lee et al. 2011).

There are different international, national and local initiatives as well as educational tools to develop CT. Almost all of them have the following points in common: The educational robotics, the visual programming environments (Scratch, Lego Education WeDo) and the video game programming (Basawapatna et al. 2010; Espino and González 2015; Kazimoglu et al. 2011; Lee et al. 2011). Our paper seeks to extend the existing research on the use of visual programming environments to work and develop CT. In our research we have used Lego Education WeDo, a material designed by Lego Group in collaboration with Massachusetts Institute of Technology (MIT). It is a simple-to-use construction set with more than 150 elements (bricks, motor, sensors and Lego USB Hub) that enables students to build and learn about the basics of programming twelve working 3D models using the Lego Education WeDo software. This tool has been used in several initiatives carried out in primary schools. Castledine and Chalmers (2011) present a descriptive qualitative case study method whose aim is to confirm the problem solving strategies that primary students use when they are working with Lego robotics, and their ability to effectively relate them to real-world contexts. The case study was conducted in a primary education classroom consisted of 23 students of 6th grade.

Mayerová (2012) carries out an experience with two groups of 3rd grade of primary education. The aim of her research was to observe and analyse the first-contact experience of these students with Lego Education WeDo. She looked for evidences that proved that the use of robotic software influenced students' ability to solve problems in a LEGO Education WeDo programming language.

Elkin et al. (2014) presents a case study that explores how robotics can be integrated and used as a new educational tool. The research presents an early educator's experience whose aim is the design and implementation of a robotics curriculum, using LEGO Education WeDo, integrated with a social science unit. The experience was carried out in a primary school in a mix-aged class of 19 students from 1st, 2nd and 3rd grade. The data demonstrated the benefits of teaching robotics in classroom.

The experience developed by Veselovskà and Mayerovà (2016) focuses on the students of 5th grade of primary education. These students developed different activities working with robotic kit Lego Education WeDo. The researchers tried to identify the activities that the pupils resolved correctly and those in which they made mistakes.

In the following parts of our paper, we provide an overview of the research. Firstly, we introduce the study by providing the method used. We have used a case study method since we focused on individuals who represented the phenomenon of our interest. We have also explored and investigated in depth the phenomenon in its natural context bounded by time and space. We also present the phases of the project developed which match with Lego Education WeDo approach to learning based on a 4C framework: Connect, construct, contemplate and continue. Secondly, we present the main results of the data analysis according to the following scheme: Students' perception of the project and teacher's perception of the project. Finally, we show the main conclusions of our research according to students and teacher's perceptions and attitudes towards the effectiveness of the project in order to help students to achieve the learning objectives, and also to begin building, coding and programming 3D models.

2 Method

The main objectives of our study were:

O1. To know students and teacher's perspectives about the effectiveness of the project developed using the visual programming environment: Lego Education WeDo
O2. To know the effectiveness of the project to help students to become familiar with a set of computational concepts and practices

The current research focused on the following research questions:

Q1. Is the project effective to help students to achieve the learning objectives of the unit and to engage them in programming and problem solving?
Q2. Do Lego Education WeDo materials provide teacher the possibilities to integrate this visual programming environment as a pedagogical tool?
Q3. Do Lego Education WeDo materials favour experiential learning?
Q4. Is it necessary to incorporate CT in primary education?

In order to achieve these objectives and answer these questions we used the case study method since we focused on individuals who represented the phenomenon of our interest, and explored and investigated in depth the phenomenon in its natural context bounded by time and space. According to Yin (1984: 23) a case study research method can be defined as "as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used." There are several categories regarding the nature of case study that Yin (1984, 1989) categorizes as exploratory, descriptive and explanatory. Regarding this classification, our study was descriptive since we described the phenomenon and the real-life context in which it took place. We carried out an intensive description of it taking into account the context and the variables that defined the situation. Merriam (1988, 1998) and Pérez (1994) also consider that a case study must be heuristic, unique, inductive and descriptive. It is heuristic as it discovers new meanings, extends experience or ratifies what is known in order to provide a full understanding of the case. It is also considered unique and characterized by a clearly idiographic approach, oriented to understand the singular reality since the real task of a case study is particularization not generalization. This feature is especially useful to discover and analyse unique situations. It is inductive since it is based on the inductive reasoning to generate hypotheses and discover relations and concepts from the meticulous system where the case takes place. Detailed observations allow us to study multiple and varied aspects and to examine them in relation to others, and within their environments. Finally, it is descriptive, as we said before, since the phenomenon is described intensely.

We used different instruments to collect data. Students' valuations were carried out by a semantic differential composed of 18 items of 7-point scales anchored by bipolar adjectives or situations (opposite-meaning terms) at each end. They also answered a small questionnaire composed of different types of questions: Open, close and short answers. On the other hand, teacher' valuations were carried out by a monitoring sheet and an interview. The monitoring sheet was composed of three parts: Objectives, contents and method with a total of 23 items of 3-point scales: Some, quite a bit, and very much. Regarding the interview, it was composed of three parts in which the teacher was asked about the context in which the project was developed, the method used, and the assessment.

Data were collected at the end of the second semester. Once the fieldwork was finished, we obtained the data and transferred them to our personal computer. Secondly, we prepared the register coding in order to process the data collected in the semantic differential, in the questionnaire, in the monitoring sheet and the interview. Finally, we carried out descriptive and inferential analyses (Mann–Whitney *U* Test). The Kolmogorov–Smirnov test was applied to verify if there was a normal distribution in the data. The significance obtained from the application of this test was 0.00, with an average of 9.46 and a standard deviation of 0.50. This demonstrated that there was not a normal distribution in the data. Moreover, the size of the sample was small. These were the two reasons why a non-parametric test Mann–Whitney *U* Test was chosen.

2.1 Phases and development of the project

The school where the research was carried out was the state-funded Infant, Primary and Secondary School *Santísima Trinidad* situated in Salamanca, Spain, in the autonomous community of Castilla y León. This school has a great experience, development, and recognition in educational innovation. It is considered a pioneer school in the use of technology in classroom, having the adequate technological resources, active innovative projects related to technology, and teaching staff that have an appropriate training in technological resources. The school is accredited with Level 4 in ICT by the regional government.

In the project developed around CT and natural science were involved a teacher of natural science who teaches the subject in English, being one of the subject of the bilingual project of the school, and fifty-two students of 4th grade of primary education. They were spread over two groups: A and B. 48.1% were boys ($n = 25$) and 51.9% were girls ($n = 27$). Of the 52 cases, 28 (53.8%) were 9, and 24 (46.2%) were 10 years old. All the participants studied the compulsory subject of natural science and had knowledge of the use of computers, tablets and interactive whiteboard. The fifty-two students had participated in previous projects in which they had the opportunity to work with the visual programming environments: Scratch and Lego Education WeDo. Moreover, 34.6% ($n = 18$) were enrolled in the Robotics workshop, and had experience in the use of the 3D modelling software, Sketch Up.

The project was implemented with two 1-h sessions over a 5-week period (10 sessions in total). All the activities were carried out in the ICT room that was equipped with computers, a projector, a digital board and headphones. In addition, for this Project the teacher had the Lego Education WeDo materials and the activity pack software installed in all the computers.

Before starting the project the teacher in charge explained and established the four phases in which the project was developed. These phases matched with Lego Education WeDo approach to learning based on a 4C framework: Connect, construct, contemplate and continue. Lego Education WeDo materials and software underpin the socio-constructivist-based learning since they emphasize the idea that students construct learning that is based on the pre-existing one. It also emphasizes the idea of learning by doing, constructionism (Papert 1980), by building things on their own using a set of tangible pieces (Ackermann 1996, 2004). Ackermann et al. (2009: 56) state that Constructionism is based on the idea that usually people learn more effectively by making things and emphasizes student-centred discovery learning since students are encouraged to work and build things with real and touchable objects using their prior knowledge. This idea is connected with experiential learning, the use of students' experience for learning "the process whereby knowledge is created through the transformation of experience.

Knowledge results from the combination of grasping and transforming experience" (Kolb 1984, p. 41).

During the first phase (*connect phase*) students were helped to build new knowledge, activating their prior knowledge through questions, presentations of the topic and different activities. The teacher, using the blog created for the subject, explained the main contents of the unit of natural science that referred to the types of machines, their characteristics and their uses in daily life. She also reviewed new vocabulary of the topic in English, and the objectives of the unit:

- To understand the importance of machines, and classify them as simple and complex machines.
- To list the most important simple machines and know how do they work.
- To know the three types of lever.
- To understand the contribution of technological progress to meeting people's needs.
- To become familiar with some mechanical movements.

During this phase she activated the students' prior knowledge not only to help them to make connection between what they already knew and what they were going to learn, but also to help them to become mentally engaged in upcoming learning and focused on the topic. The activities that were going to develop in the project involved the use of Lego Education WeDo toolsets and software. Although the participants in the research were familiar with them and the terminology was assumed, the teacher reviewed the vocabulary that referred to this material.

In the second part of this first phase, the teacher reviewed the rules of use of the Lego material that were established in the framework of the Erasmus+ project: *Creating Tomorrow's Schools Today* (*CTST*) *2014–2017* (http://creatingtomorrowschoolstoday.blogspot.com.es) in which the state-funded school Santísima Trinidad participates together with other European schools from Germany (Erich Kästner Grundschule), France (Institution Sainte-Thérèse Les Cordeliers), Italy (I.C.S. Ignoto Militi), Polland (Zespół Szkół Społecznych nr 3) and Wales (Ynystawe Primary School). The main aim of this Erasmus+ project is to compile a multidisciplinary and multilevel European Teacher's toolkit packed with didactic resources and practical classroom strategies. These rules were:

- Hand out the Lego Education WeDo boxes and wait without opening them.
- Listen to the teacher who is going to give you the instructions.
- Open the boxes when the teacher tells you and start working.
- Lego bricks can only be in the boxes or in the 3D models. They cannot be on the table.
- Students cannot exchange the Lego elements.
- Do not continue working when they teacher asks you to stop. Leave the Lego bricks and raise your hands. Get ready to listen.
- Gather up the Lego bricks and check around you. If your classmates have dropped a Lego element tell them but do not pick it up for them.
- Collect all Lego Education WeDO materials.

After reviewing the rules of use of the Lego material, she provided the students the dossier that included all the possibilities offered by Lego Education WeDo materials and the purposes of its software.

In the last part of the connect phase, the teacher projected four videos that referred to each of the phases in which Lego Education WeDo materials are based on: Connect, construct, contemplate and continue. The participants could observe specific examples of any of these phases.

In this first phase teachers gave students not only the information that they needed to be able to complete the following tasks, but also to show them the Lego materials with which they were going to work. The teacher also observed if the students had really understood what they had to do, and if they had appreciated the relevance of what they were learning.

In the second phase (*construct phase*) students had the opportunity to construct the different 3D models provided by Lego Education WeDo, using their hands and minds, and with the help of the step-by-step instructions provided for each model. The teacher divided students into different groups of three people: One of low level, one of intermediate level, and one of advanced level. This division emphasized the importance of heterogeneous groupings of collaborators. According to the concept of the zone of proximal development (ZPD) developed by the Russian psychologist Lev Vygotsky (1978), students' learning is greater when they study in a community, in a collaborative way that provides them a supportive framework that allows them to do different activities that cannot be accomplished individually (Brown and Collins 1989; Duffy and Cunningham 1996; Roschelle and Teasley 1995). Each group was given a Lego Education WeDo Construction Set in order to construct two 3D models: Dancing Birds and Smart Spinner. The students built the models, following the instructions provided. After finishing the constructions, they connected each model to the computer, which had installed LEGO Education WeDo Software and WeDo Activity Pack, using the Lego USB Hub, and started programming them. Students programmed the Dancing Birds in order to make sounds and dance using a pulley and belt drive system. In the case of the Smart Spinner, students had to programme it to spin a top and release it and to use a motion sensor to turn off the motor when the top is released.

In the third phase (*contemplate phase*) students had the possibility to observe what they had constructed and to reflect about it. This brought them the opportunity to deepen their understanding and develop different connections between their previous knowledge and the new experiences. They could go farther and experiment with more complex challenges that they shared with others.

The teacher asked students to observe what they had built, and reflect on what they had done and learned. They shared insights that they gained during this phase, and showed their ideas with their classmates, drawing the main conclusions about the learning experience. During this phase the teacher asked questions to guide the learners' presentations and be sure that the learning was explicit since when they verbalized what they had done, they consolidated what they had learned.

In the last phase (*continue phase*) students were encouraged to carry on building, changing or adding features to the 3D constructions done in order to develop new models. In this phase the teacher of natural science encouraged students to change the model that they had showed to their classmates, and try to create something new, using the contents that they had learned.

3 Results

The results of the case study will be described according to the following scheme: Students' perception of the project and teacher's perception of the project.

3.1 Students' perception of the project

Students' valuations about the development of the project were carried out by a semantic differential composed of 18 items of 7-point scales anchored by bipolar adjectives or situations (opposite-meaning terms) at each end. They also answered a small questionnaire composed of different types of questions: Open, close and short answers. These instruments were adapted from a research led by García-Valcárcel (2015) and used to gather information about the school, the students' socio-demographic characteristics and the project.

Regarding the results, we can generally state that the students assessed in a positive way the project developed around CT and natural science using the visual programming environment, Lego education WeDo. As shown in the table below (Table 1), the mean of the majority of the items of the semantic differential were between 6 and 7. The students believed that the project developed was funny (6.77); useful (6.69); and interesting (6.63). They emphasized that they had loved this way of working (6.77); and wanted to learn more about the topic of this unit of natural science (6.77). The participants also stated that they understood the activities (6.65), they maximized time (6.17), they learned more things than usual (6.52), and they had the opportunity to develop the tasks in groups (6.46). Regarding their opinions about the teacher in charge, they considered that she had an important role since she clearly explained what they had to do (6.71); she helped them to develop the tasks (5.88); and she played a relevant role as a guide, showing them what was right or wrong (5.81).

With respect to the means obtained in the items that referred to CT, we emphasized the positive results of students' perceptions about the possibilities offered by the visual programming environment, Lego Education WeDo, to build 3D models (6.31) and learn about the basics of programming them (6.50), as well as to promote creative thinking to make the 3D models (6.37), to reflect about the activities (6.42), to solve problems in a logical way (6.29), and to know the results of their decisions (6.38).

We calculated the Mann–Whitney *U* test to determine whether there were statistically significant differences (CI 95%) between boys and girls in their assessments of the items of the semantic differential. The data analysis indicated that there were statistically significant differences in the items that referred to:

- I have learned the basics of programming.
- The activities done with Lego WeDo have allowed us to reflect.
- I have learned to build models in 3D.
- The project has allowed us to solve problems in a logical way.
- I have learned to think creatively to make the 3D models.
- Lego WeDo has allowed us to know the results of our decisions.

Regarding the results of the Mann–Whitney *U* Test (see Table 2) of the items 'I have learned the basics of programming' and 'I have learned to build models in 3D', we point out that there were statistically significant differences between the mean of boys (item 15 $\bar{x} = 6.96$; and item 24 $\bar{x} = 6.92$) and girls (item 15 $\bar{x} = 6.07$; and item 24 $\bar{x} = 5.74$). The boys considered that they learned better how to build these 3D models and the basics of programming them. On the other hand, the results of that non-parametric test in the items that referred to 'the activities done with Lego WeDo have allowed us to reflect', 'the project has allowed us to solve problems in a logical way', 'I have learned to think creatively to make the 3D models', and 'Lego WeDo has allowed us to know the results of our decisions' showed that there were also statistically significant differences between the

Table 1 Semantic differential

It has been boring	6.77	It has been funny
I have lost time	6.17	I have maximized time
I have learned less things than usual	6.52	I have learned more things than usual
I have not learned about the basics of programming	6.50	I have learned about the basics of programming
It has not been interesting	6.63	It has been interesting
I have not understood what we have done	6.65	I have understood what we have done
The activities done with Lego WeDo have not allowed us to reflect	6.42	The activities done with Lego WeDo have allowed us to reflect
I am no longer interested in this topic	6.77	I want to learn more about this topic
It has been useless	6.69	It has been useful
I do not like this way of working	6.77	I love this way of working
The teacher has not helped us	5.88	The teacher has helped us
The teacher has not given us clear instructions	6.71	The teacher has explained clearly what we had to do
I have not learned to build models in 3D	6.31	I have learned to build models in 3D
We have not done the exercises well, working in group	6.46	We have done the activities well, working in group
The project has not allowed us to solve problems in a logical way	6.29	The project has allowed us to solve problems in a logical way
I have not learned to think creatively to make the 3D models	6.37	I have learned to think creatively to make the 3D models
Lego WeDo has not allowed us to know the results of our decisions	6.38	Lego WeDo has allowed us to know the results of our decisions
The teacher has not indicated what was right or wrong in our work	5.81	The teacher has indicated what was right or wrong in our work

Students' valuations about the development of the project

mean of boys (item 18 $\bar{x} = 5.88$; item 26 $\bar{x} = 5.60$; item 27 $\bar{x} = 5.72$; and item 28 $\bar{x} = 5.76$) and girls (item 18 $\bar{x} = 6.93$; item 26 $\bar{x} = 6.93$; item 27 $\bar{x} = 6.96$; and item 28 $\bar{x} = 6.96$). In these cases we emphasized that girls assessed better all these items.

The majority of the students, 61.5% (n = 32), stated that what they liked most about the activities developed in the project was the possibility that they had to build the 3D models and learn about the basics of programming. Another 23.1% (n = 12) considered that they could work as a team, sharing their ideas and working together. Finally, 15.4% (n = 8) emphasized that this project allowed them to work playing. They believed that they learnt more than in a traditional lesson.

Regarding the points that they like least, most of students, 46% (n = 24), answered that nothing. On the other hand, 32.7% (n = 17) pointed out that they did not have enough time to build and learn the basics of programming the models, so they considered that they needed more practice to learn how to do it. 11.5% (n = 6) also indicated that it was quite difficult to work as a team since they did not agree with the development of the activities or because some of the classmates wanted to do everything without taking into account their partners' opinions. 3 of the 52 cases (5.8%) stated that what they like least was the resources they had since they believed that they did not have enough tools, and it would be

Table 2 Independent-samples Mann–Whitney *U* test

Gender	Mean rank	Sum of ranks	Mann–Whitney *U*	Sig.	Z
Item 15					
Boy	35.58	889.5	110.50	.000	−4.813
Girl	18.09	488.5			
Item 18					
Boy	14.42	360.5	639.50	.000	−6.228
Girl	37.69	1017.5			
Item 24					
Boy	39.04	976.0	24.000	.000	−6.465
Girl	14.89	402.0			
Item 26					
Boy	13.80	345.0	655.00	.000	−6.448
Girl	38.26	1033.0			
Item 27					
Boy	13.42	335.5	664.50	.000	−6.698
Girl	38.61	1042.5			
Item 28					
Boy	13.98	349.5	650.50	.000	−6.472
Girl	38.09	1028.5			

great to update them. Finally, just 3.8% (n = 2) considered that the thing they liked least was to destroy what they had built.

Students were also asked about the problems they had to build and programme the working models. More than half of the students, 51.9% (n = 27), indicated that they did not have problems at all. On the contrary, 15.4% (n = 8) answered that they had problems to programme the models and this demotivated them to carry on with the tasks. The students also answered that they had problems with the resources (13.5%, n = 7) or to work as a team (11.5%, n = 6). Just 7.7% (n = 4) considered that they did not have enough time to finish.

3.2 Teacher's perception of the project

Teacher' valuations about the development of the project were carried out by a monitoring sheet and an interview. The monitoring sheet was composed of three parts: Objectives, contents and method with a total of 23 items of 3-point scales: Some, quite a bit, and very much. Regarding the interview, it was composed of three parts in which the teacher was asked about the context in which the project was developed, the method used, and the assessment.

The analysis of data revealed that the teacher evaluated the project developed around CT and natural science using the visual programming environment, Lego Education WeDo, in a positive way. She assessed as 'very much' the students' achievement of the learning objectives of the unit of natural science that referred to the types of machines, their characteristics and their uses in daily life. She considered that students worked and assimilated the contents through the development of the four C phases in which the project was developed, and she assessed as very interesting the contents developed for the students who participated in it. She stated that most students were able to integrate new contents with their prior knowledge to generate significant advances in the topic.

She believed that the success of the achievement of the learning objectives was due to the tasks carried out. Specifically, she made the following assessments: (a) She stated that the activities allowed students to be fully immersed in what they were doing and creating, having the possibility to transfer the knowledge they already had to a specific area. (b) The tasks motivated the students and aroused their curiosity, being free to explore the possibilities to build and learn the basics of programming the different 3D models. (c) They facilitated the students' active role, being solution-seekers, and the collaborative work. She emphasized that the fact of working collaboratively implied that students had a better understanding of the topic and an active role towards the community. Finally, she believed that (d) they fostered the students' creativity, problem solving skills and critical thinking.

Technological resources were generally assessed very positively. The teacher considered that: (a) They were very useful and facilitated the achievement of the objectives and contents of the unit. (b) These technological resources contributed to motivate the students who were favourably predisposed towards the experience from the first moment that they saw the technological materials they were going to use (Lego Education WeDo materials, tablets and computers). (c) They helped to explore the possibilities to solve problems that could be more difficult to solve without them, and allowed students to develop problem-solving skills such as initiative, creativity and trial and error.

The teacher also evaluated as very appropriate the type of grouping proposed. She considered that the distribution of 3-student groups, one student of low level, one of intermediate level, and one of advanced level, had favoured the development and success of the tasks, improving the students' performance significantly. The fact of working in groups allowed the students to play different roles as builders, programmers, or presenters during the development of the project, and to promote positives attitudes towards the peers. Regarding the facilities and space used, she stated that they met the requirements for developing the project of CT and natural science in an education environment. Although the teacher was completely satisfied with what had been accomplished, she also affirmed that it would be necessary to have more practice to consolidate learning.

4 Conclusion and discussion

Results showed that the project developed around natural science and CT was effective in order to help students to achieve the learning objectives of the unit, and also to begin building, coding and programming 3D models.

Our research provides evidences of students and teacher satisfaction towards the project, considering that the use of Lego Education WeDo materials helped them to understand better the activities and learn more things than usual in a useful, funny and interesting way (Kazimoglu et al. 2011). The fact of working together also gave them the opportunity to teach, learn, help and motivate each other.

During the project, a strong students' engagement, enthusiasm and motivation was observed in the development of the different tasks, constructing and programming the 3D models, since they had the possibility to learn by doing (Sorbi et al. 2014). This experiential learning favoured the development and success of the tasks developed, and improved their performance significantly (Kolb 1984) since they could manipulate the Lego bricks, sensors and motors and this facilitated to remember what they had learnt. Students had the possibility to learn through reflection on doing in authentic situations. They applied their knowledge to real-world problems and became familiar with some mechanical movements, the types of machines, their characteristics and their uses in daily life. As a result, the use of Lego Education WeDo materials was useful to transmit and acquire the contents and objectives of natural science in Primary Education.

To a great extend, the success of the natural science and CT project relied on the teacher' role. She played a fundamental role as a guide, explaining clearly what they had to do, and showing them what was right or wrong. The students stated that her help was fundamental for the success of the project since they worked more effectively with her guidance (Zapata-Ros 2015). On the other hand, the research showed students' active role, playing different roles as builders, programmers, or presenters.

The careful design of the project and the development of the tasks did not only allow students to achieve the objectives and contents of the unit but also to verbalise the problems they had and the solutions they found. Moreover, the teacher provided the students the possibility to reflect upon their learning during the four C phases (connect, construct, contemplate and continue) in which the experience was developed (Pinto-Llorente et al. 2016b).

This experience also helped them to develop the majority of the key competences established in the European Reference Framework and the Spanish Education System, specifically those that refer to linguistics communication competence; Mathematical competence and basic competences in science and technology; Digital competence; Learning to learn; Social and civic competences; and Sense of initiative and entrepreneurship.

The potential usefulness of the visual programming environment Lego Education WeDo lies in allowing students to get awareness of CT (Kazimoglu et al. 2011), and promoting critical thinking and problem solving skills. There were evidences of the possibilities offered to reflect and think creatively about the opportunities they had to fulfil the activities correctly, to know the results of their personal or group decisions, and to solve the problems in a logical way (Bers et al. 2014). Our results around the benefits of the use of this visual programming environments to help students to acquire the skills of critical thinking, creative thinking, problem solving, reflection, collaboration, communication, and time management agree with those obtained in the researches carried out by Atmatzidou and Demetriadis (2012); Barak and Zadok (2009); Barker and Ansorge (2007) and Goikhman et al. (2016).

To sum up, the project and its results have proved the potential of Lego Education WeDo materials and software in the subject of natural science to promote CT, and to engage primary education students in programming, and problem solving. This project has allowed the teacher to integrate this visual programming environment as a pedagogical tool to help students to familiarize with technology and its uses in their daily life (Sorbi et al. 2014). Students have been able to create their own simulations, and to share them in a learning community. Students have had the possibilities to become familiar with a set of computational concepts, which are common in programming language (coding, programming, sequence, loops, parallelism, events, conditionals, etc.) and computational practices (testing and debugging, reusing and remixed, and abstracting and modularizing) (Pinto-Llorente et al. 2016b; Sorbi et al. 2014). It is important and necessary to incorporate CT in primary education and in core content areas (Lu and Fletcher 2009) since it is fundamental in the current society.

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