Development of Basic Spatial Notions Through Work with Educational Robotics in the Early Childhood Education Classroom and Analysis of Qualitative Data with WebQDA Software

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Abstract. With the current research work, it is intended to develop basic spatial concepts (front, back, up, down, right and left) through a didactic proposal based on the use of educational robotics in the classroom of Early Childhood Education. The Roamer Robot is specifically used for the potential it offers to adapt to pupils' needs and the characteristics of all activities. For the work in the classroom, a series of contextualised activities are presented in different types of content, which is why Roamer's versatility as a learning tool is enhanced.

With this research project we intend to know the differences on the acquisition of these concepts before and after the intervention in the classroom with the Roamer robot. For this, a qualitative approach research has been designed using as investigation instruments an experimental test and a drawing test that have been adapted to the evolutive characteristics of children in Early Childhood Education. The WebQDA software has been used to support the qualitative data analysis.

In general, it is concluded that the work with robotics in the Early Childhood Education classroom improves the acquisition of basic spatial concepts in these pupils. However, the right and left concepts are still the most complicated to acquire and assimilate.

Keywords: Spatial notions · Educational robotics · Childhood education
Qualitative analysis · WebQDA

1 Introduction

This research work results from the completion of a pilot study prior to the doctoral thesis project "Educational robotics as a support to the development of basic spatial notions in Early Childhood Education" that is being carried out in the Department of Didactics of Experimental Sciences and Mathematics of the University of Extremadura (Spain). In this pilot study, the application and treatment of qualitative data is carried out through the WebQDA software [1].

A. P. Costa et al. (Eds.): WCQR 2018, AISC 861, pp. 22–33, 2019.
https://doi.org/10.1007/978-3-030-01406-3_3

A proposal of educational intervention is presented for the development of basic spatial notions in Early Childhood pupils through the robotic use and programming, specifically the use of the Roamer Robot in the classroom. For this, all the aspects that influence the teaching-learning process have been taken into account and that is reflected through the classroom methodological work based on the EMO (experimentation, manipulation and observation).

The process of development of basic notions implies the work through a series of parallel phases which are related to the psychoevolutive needs of pupils of these ages. Thus, the development of the body scheme itself has been worked on as well as the projection on objects external to our body: Roamer.

In order to obtain information, a data collection is carried out before and after the practical intervention with Roamer through a graphic test and an experiential test that is analysed through the WebQDA software. Through this process of collection, treatment and analysis of data, it is possible to analyse if there are significant differences when working in the classroom with an active methodology based on Robotic programming. The results obtained allow teachers to make decisions about the methodology and tools used in the daily work in the classroom, in order to carry out an educational intervention according to the pupils' needs, their context and the social demands in which we find ourselves immersed.

2 Statement of the Problem and Context

The child in pre-school education is in the preoperational stage (2–7 years) according to Piaget's development theory, in Feldman [2]. In this stage the child develops the symbolic function to act and understand the world around him/her; however, according to this author, can not develop organised formal and logical mental processes. Therefore, it is believed that in the early childhood education classroom it is fundamental to work with robotic programming, since it will help the child to structure sequences and mental processes with a functional and significant logic. This idea is developed as Computational Thinking which "involves solving problems, designing systems and understanding human behaviour, making use of the fundamental concepts of computer science" [3]. In order to work on computational thinking in the children's classroom, it is necessary to carry out a problem solving process that helps the child to structure his/her thinking and develop a logical reasoning. This same competence can be applied to any educational area and stage, although in the stage of Early Childhood Education it becomes more relevant, since through the development of these strategies, cognitive aspects that can help overcome the limitations of preoperational thinking are worked on: focus, egocentrism, irreversibility, incomplete understanding of the transformation [4].

The work with robotics in Early Childhood Education can help the development of spatial basic notions related to the child's own body and to objects around him/her. The structuring of the notion of space gains momentum, as the child develops the dynamic control and coordination of his/her own body, as well as the awareness of objects external to him/her.

Manuel Valencia, director of Argan Bot in an interview to the newspaper "El español" [5] defends that "with programming we manage to structure the head so that problems can be solved in a more logical way". This way, when the child faces a problem he has to look at his cognitive structure to analyse the situation and solve the problem, "milestones" that the child has around to which he/she will establish "routes" to create the work procedure, and then choose the most suitable one for solving the problem, as stated in the Theory of Nuclear Concepts (TCN) [6].

Taking into account the above, some aspects that justify our research Project can be named.

- It is very important to analyse the development of knowledge and control of one's own body regarding the spatial orientation of children in Early Childhood Education using robotic programming through Roamer.
- Analyse and observe if there are differences in the results extracted before and after the educational intervention to check if there are significant differences that allow us to make decisions to improve the teaching-learning process.
- It is worth highlighting the legislative contextualisation of the use of robotics in the classroom. For this, Roamer will be integrated as a tool that will help to enhance the pupil's spatial development as a main aspect and other secondary content related to all areas of the official curriculum of Early Childhood Education in our Autonomous Community of Extremadura.
- Through the work in the classroom, pupils are provided with a globalised approach [7] as an essential principle for educational practice in Early Childhood Education. Thus, through educational robotics, contents of various kinds are worked on: mathematical, language, observation of the environment, socialisation, etc.
- In addition, it is worth highlighting the principle of playing and motivation provided by the work with educational robotics in the classroom. It is an aspect closely linked to the learning needs of children of these ages. This way, pupils' main interests are always highly considered.

Taking into account all these aspects, the main objective of the research is to analyse whether the work in the classroom with educational robotics can improve the spatial orientation of the Early Childhood Education pupil, in terms of his/her own body and external objects. Through the work of this objective it is intended to answer the following research question: do pupils improve the acquisition of basic spatial concepts with the use of educational robotics in the classroom?

The evaluation of the learning process is fundamental, since it offers data about development and acquisition of new knowledge. The following definition of evaluation is highlighted [8] "it is that learning activity that is evaluated to check the knowledge, skills and competences that are being acquired, as well as the requirements and conditions that must be met". Using suitable instruments and tools for data analysis is very important. In the stage in which the present study, Early Childhood Education, is developed, pupils' characteristics must be taken into account in order to develop the evaluation activity.

The WebQDA software, chosen to perform data processing and analysis, allows the completion of all the tasks involved in data processing in our research: organisation, categorisation and analysis of those data [1].

WebQDA is software that has been created by the company Micro IO and Ludomedia in collaboration with the University of Aveiro [9]. The Spanish version was developed with the support of the CiberDidact research group of the University of Extremadura (Spain). It is specific software aimed at qualitative research in general, it allows the analysis of graphic data: images—videos and text. It is also a tool that allows you to edit, store and organise documents, where you can create categories, code, control, filter, investigate and consult research data.

The main reason for choosing WebQDA software for data processing is that it allows the incorporation of different types of sources: textual, graphic, sound, etc. When working with Early Childhood Education pupils, the tests designed are very graphic and this software allows to work with them in a very easy and organised way. In addition, it is important to highlight the ease of organisation of research data through the category system. The fact of being able to share the project with other users is very useful to enhance the collaborative work.

3 Methodology

With regard the proposed objective and the research question, this study uses the qualitative method based on data collection instruments by the teacher's direct observation and by analysis of WebQDA software in its latest version 3.0. This tool was necessary to analyse if the work in the classroom with educational robotics through a work methodology based on exploration, manipulation and observation (EMO).

3.1 Sample

The selection of the sample was obtained by a non-probabilistic convenience sampling. The selection criteria that were taken into account for the research were the following:

- 1 group of pupils enrolled in 5 years of Early Childhood Education.
- The selected pupils must have developed a series of basic contents: know numbers, some letters, colours, etc.
- Pupils must attend school continuously so that an ongoing investigation may be carried out.

An attempt was made to find a sample that, in keeping with the above criteria, was accessible to the researcher, since she is the group's tutor. The sample chosen was determined from the 5-year-old children of CEIP Ntra. Sra. of Chandavila from the town of La Codosera (community of Extremadura—Spain). It is a group of 7 pupils with different characteristics and motivations but with a good level of cognitive development; it is worth mentioning the participation in the group of a child with Special Educational Needs.

Of the 7 participants who regularly attend school, all of them have actively participated in the research, since their parents have expressed their prior written authorisation. It is a very small group which allows a very individualised treatment.

3.2 Phases and Timing

As far as the phases of the research are concerned, the study began with an initial phase of data collection and research design. The practical intervention lasted 3 months, from the end of November to the beginning of February. After this practical intervention, the final phase of data processing was carried out. Due to the characteristics of the work methodology employed in Early Childhood Education, delimiting the timing in the number of specific sessions is complicated, since the work is carried out from a globalising perspective, where contents are constantly interrelated. Due to this characteristic, the following work plan is defined (Table 1):

Table 1. Timing of the research.

Phases	Number of sessions	Description
Initial evaluation	2	Drawing[1] and Experiential Evaluation[1]
Practical activities with the Roamer Robot and psychomotor skills	34 Specific sessions and sporadic sessions contextualised in the contents and needs of the group	Combined activities of educational robotics and psychomotricity and contextualised in the classroom, for example. In the daily assembly the protagonist of the day will solve a proposed challenge: directing the Roamer to the letter "L"
Final Evaluation	2	Drawing[2] and Experiential Evaluation[2]

3.3 Instruments Used

The instruments for data collection that have been used have been selected and designed taking into account the characteristics of the participants and the research itself. Below each selected instrument is described, as well as its justification and application process in our research.

Experiential Evaluation

This activity consists in the following: the pupil identifies a certain part of his or her partner's body related to the concepts under study: front-back. Up-down, right left. This identification was made keeping in mind the most common bodily positions: front, back and lying down. One of the pupils played the role of mannequin (he could not move or say anything to his partner; this figure will change so that everyone can participate). Another colleague placed stickers of a certain colour in the body part of the manikin indicated by the teacher.

This experiential evaluation was carried out to know if the pupil is able to differentiate the concepts that are going to be worked on in a body other than his/her own. In addition, the position of the manikin body is changed to check this same acquisition in different axes of reference: front, back, horizontal. The assessment was recorded

through photographs of the mannequins after placing the stickers to check the positive and negative results.

The distribution of coloured stickers for each identified concept is the following (Table 2):

Table 2. Distribution of colours for each concept to be identified in the experiential test.

Front	Back	Up	Down	Right	Left

Evaluation by Drawing

The pupils were presented with a drawing already presented that they had to colour according to instructions. It is a drawing in which we can observe different children in different body positions in which their body axis is not equal to the normal axis of reference (standing). These children are playing different games and one can observe objects that the participants must identify and solve in the best way. The indications are the following:

- María is playing hopscotch: color in dark green the bush that is on the RIGHT of María and of light green the bush that is on the LEFT of María.
- Paula does not play hopscotch, draw a ball in FRONT of Paula.
- Draw a rainbow in the BACK of the bushes.
- Pedro does the somersault, surround the UPPER part of his body with a red colour and the LOWER part of his body with a blue colour (Fig. 1).

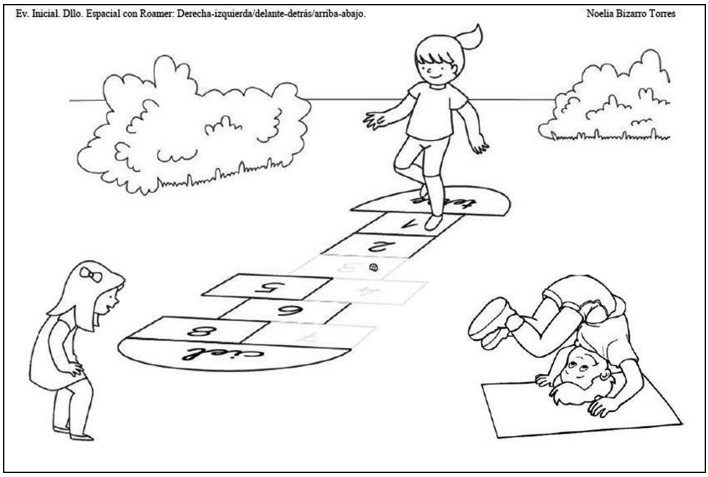

Fig. 1. Drawing evaluation test.

3.4 Analysis Procedure

After the data collection with the two instruments used, the data analysis was carried out with the support of the WebQDA software.

Taking into account the whole process described above and the evaluation instruments, for the analysis procedure, a qualitative analysis of the tests to identify previous knowledge in the initial evaluation and of the evaluation tests at the end of the process was carried out.

4 Activities Performed

In accordance with the proposed methodology, the following activities were developed:

1. **First phase:** Research design. In this phase, the problem that was intended to be solved was raised. In addition, the spatial concepts that were intended to be worked on and evaluated in the pupils were chosen, the research was designed and the intervention project in the classroom was also programmed, based on the application of activities with educational robotics and bodily activities.
2. **Second phase:** Initial evaluation. The experiential test and the drawing test were carried out just before starting the work in the classroom. This evaluation allowed to know the previous knowledge that our pupils have regarding the contents that are going to be worked on.
3. **Third phase:** Intervention in the classroom. The intervention in the classroom was carried out in the number of sessions initially scheduled. On the one hand, contents from different areas were worked on in the classroom with educational robotics (Fig. 2), thus, the content was presented in a globalised way, taking advantage of all the potentialities of this tool. And on the other hand, basic psychomotor activities have been developed (Fig. 3) that complement the activities with robotics and that are related to the concepts to be worked on.

Fig. 2. Activities in the classroom with the Roamer Robot.

Fig. 3. Activities in the psychomotricity classroom.

4. **Fourth phase:** Final evaluation[2]. Just after the intervention in the classroom with educational robotics and psychomotricity activities, the experiential test and the drawing test were repeated. The aim is to observe if there are any significant differences with regard to the initial evaluation.
5. **Fifth phase:** Data processing through WebQDA software. In this phase several sequenced tasks were carried out:
   - Data transfer to WebQDA: digitised copies of the two tests were incorporated. In the case of the experiential test, photographs were used and in the case of the drawing test, the drawing itself was incorporated into the internal sources of the software. Through WebQDA, those points referring to the contents studied have been indicated and their resolution has been described.
   - Creation of the category system: Subsequently, a system of categories was created to categorise the pupils' answers. The categories are related to the 6 concepts that are being evaluated and the process of acquiring them.
   - Data query: The pertinent consultation was carried out to obtain results that are presented in the following section (Fig. 4).

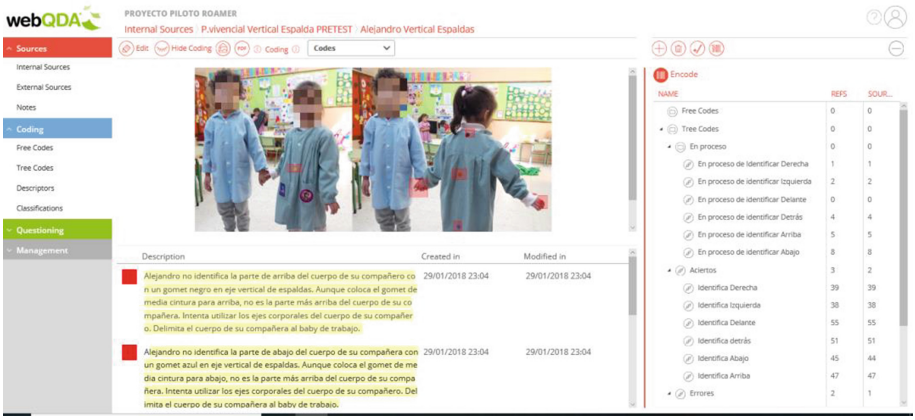

Fig. 4. Data processing with WebQDA Software.

5 Results

Below are the results of the different tests we have carried out taking into account the comparison of the initial and final moments of its application.

In Fig. 5 you can see the results of the experiential test—front. In the initial test, pupils showed greater difficulties in identifying left and right, but in the final test it can be seen how most of them have overcome these difficulties. It is worth noting the difficulty of this test because they are identifying left and right in a mirror position, i.e., in a position contrary to that of their own body.

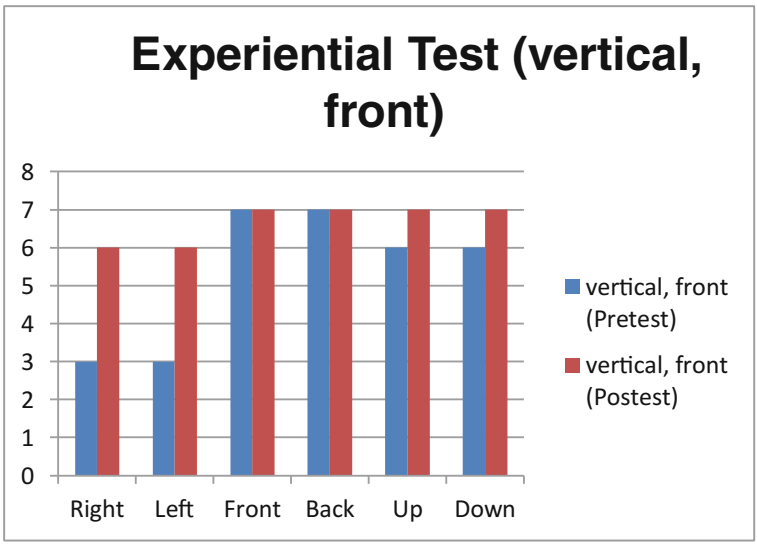

Fig. 5. Experiential test results (front) pretest and postest.

In Fig. 6, referring to the vertical experiential test—back, pupils have improved the identification of all concepts except the concept of left and right, which is still the most complicated.

In Fig. 7, regarding the horizontal experiential test, it can be observed how the correct identification of the concepts which are asked to pupils has improved significantly. It should be noted that in the horizontal position they have been able to identify the right and left of their partner.

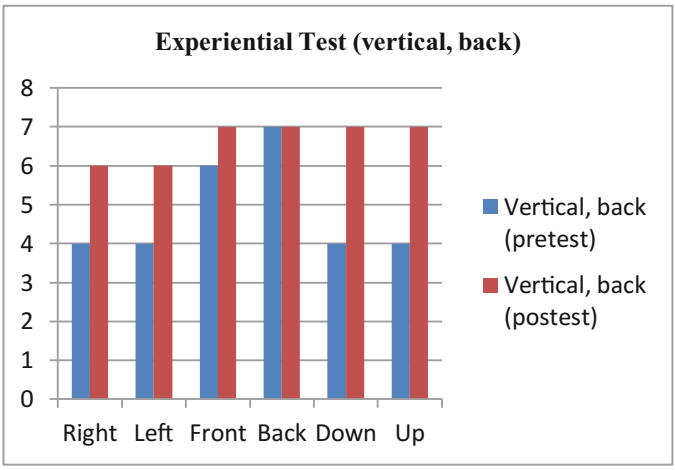

Fig. 6. Experiential test results (back) pretest and postest.

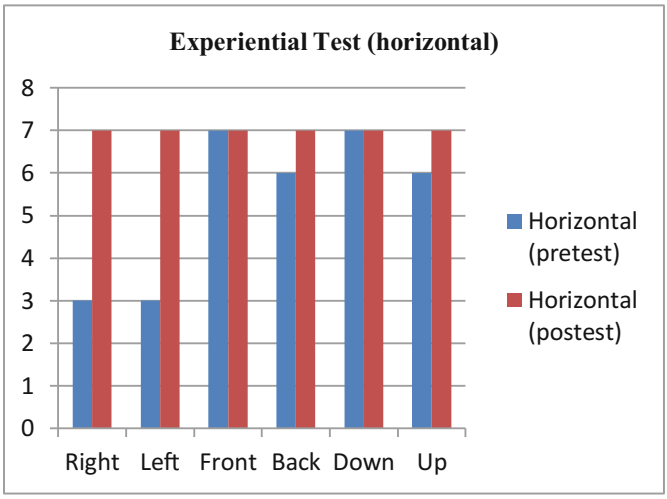

Fig. 7. Experiential test results (horizontal) pretest and postest.

Figure 8 shows the results obtained from the drawing test. Pupils initially presented problems for the identification of the right and the left and also up and down for the position of the figure in which they had to identify these last concepts (Pedro in the drawing test). However, in the final evaluation it has been possible to observe how the pupils improve the identification of all these concepts, although they still have difficulties to identify the concept *down*.

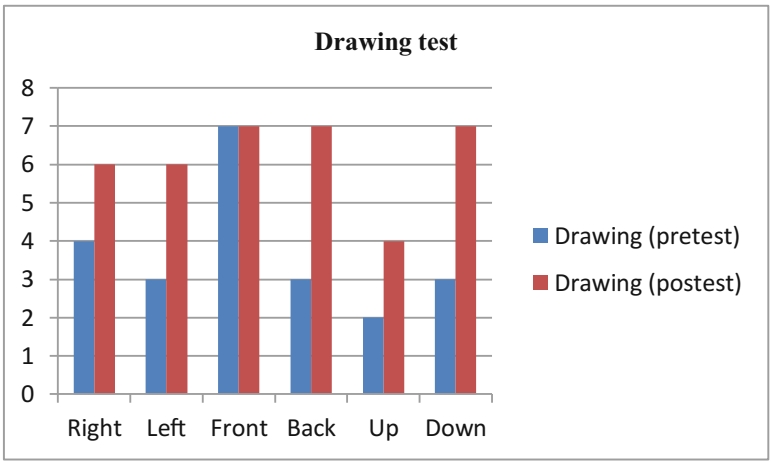

Fig. 8. Initial and final drawing test results.

6 Conclusions and Suggestions

In general, it is concluded that working with robotics in the classroom improves the acquisition of basic spatial concepts in children in early childhood education and helps the child to flexibilise the characteristics of irreversible thinking that Piaget defends in Feldman [2]. However, it must be borne in mind that the concept of right and left is the most complicated for these pupils, since in all the tests carried out one can observe the difficulties that the pupil has for its identification. For this reason, these concepts should be more thoroughly worked on in the activities of the intervention in the classroom.

As far as the questions raised are concerned, the observation, analysis and conclusions on the differences between the tests applied in the two moments of data collection have been carried out. In addition, an educational intervention project has also been designed with manipulative materials and attractive activities for pupils regarding educational robotics in the classroom and psychomotricity, respecting the principle of globalisation, motivation and play. This way, pupils have worked favourably in the classroom with the chosen material. They were motivated and active participants in all activities, so the work with robotics in the classroom is very positive, since it favours the application of problem solving strategies and keeps the pupil motivated. Through this process we have worked on the development of "Computational Thinking" [3].

Using the WebQDA computer software, it has been possible to organise, structure the sources extracted from the evaluation tests; it has also allowed to categorise each concept to be valued and thus the results have been obtained in a very practical and useful way. However, in the thesis project, the comparison of these two evaluation tests is considered with other very useful ones which will allow extracting and comparing results. Thus, we intend to replicate this study using also the extraction of Pathfinder Associative Networks [6], to analyse the cognitive structure of the pupil and the application of a standard test that evaluates the concepts worked on.

Taking into account the conclusions drawn and the proposed limitations, we suggest the replication of the study with a larger sample and observing differences compared to the use of a traditional methodology in the classroom, that is, without the use of robotics in a control group.

Acknowlegement. This work was supported by the European Union and Gobierno de Extremadura under Grant FEDER: Programa Operativo FEDER de Extremadura.

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