Modification of Scientific Skills through a Robotics Ecology Program

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Abstract

An experiment of social responsibility applied through a robotic ecology program based on three pedagogical phases was developed: (a) Social ecological intelligence, (b) Social scientific task, (c) Scientific reflection. A contaminated beach context was approached, from which elementary school students recycled waste to develop basic robotic prototypes. Knowledge, observation and reflection skills were modified. Similarly, environmental awareness was considered as an implicit construct in the reflection, which was developed during the ecological approach experience. Although the dimensions improved, the differences obtained in knowledge capacity were not significant in the group comparison.

Keywords

Environmental Awareness, School Robotics, Scientific Skills, Sustainability.

1. Introduction

En [1] evidences of the ecological transformation from the work with recycling in the city context are reported. With a similar experience, we seek to continue other works that investigate STEAM work modalities with the production of didactic elements based on educational robotics [2, 3, 4]. This work reports the results of the development of scientific skills based on a Robotic Ecology program in the interrelation of the school-society type. Contributes to the study of the basic skills of observation, inquiry and reflection through the use of creativity coupled with caring for the environment. These evidences reflect the first results in learning in science and technology from an experiential didactics applied in a literal Latin American coastal context, which reflect both the increase in these skills, the development of social responsibility, and the attitudes of ecological care.

1.1. Robotic Ecology for Education

The robotic ecology proposal bases the work of robotic didactics based on overcoming the difficulties to learn science and technology. In the proposal of [3], the needs of scientific learning can be understood from the development of socio-emotional skills through STEAM. This is evidenced in other studies that have reflected the development of interrelationships that outline the behavior of the type: individual> computer> robot [5], as well as work in groups with learning difficulties [6]. Since gamification, social learning has been established in educational management to develop emotional components in students, although efforts still continue in the social field, developing the commitment of the individual> learning type [7, 8, 9], when robotics is an intermediary, without generating strong evidence on engagement> interaction [7]; and better stimulation with the inclusion of the robot in

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STEM practice [2]. In other studies, simulation algorithms already show attempts to improve the quality of human> robot collaboration [9]. Thus, in the language area there are already improvements in the search for learning in orality and vocabulary [8], and this is also already corroborated in the collaborative investigative and communicative interaction in virtual education [10].

In more palpable evidence in the educational area, other proposals have been found with innovative and playful methodological structures such as Design Thinking [11], which help to mediate prior knowledge, new knowledge and cognitive feedback [4, 11]. In this sense, we base the experience of an educational robotics program from the recycling of solid waste in a particular context. The proposed didactic processes were based on the scheme: SEI [Social Ecological Intelligence] > SST [Social Scientific Task] SSR [Social Scientific Reflection], each one based on the theoretical proposals for the development of ecological and social intelligence [12, 13, 14].

With SEI, it was sought to generate cultural knowledge in students and the recognition of the diversity of a polluting environment, in order to achieve the capacity for inquiry and generate new knowledge through social self-questioning. Then, SST allows the student to use the objects, prevent damages to his person, and manage to propose robotic sketches in the classroom through the replication of other pre-existing ones. Regarding the SSR phase, pedagogical questions are generated to awaken two types of reflection, one of a cognitive type, on robotic models; and others, of a social nature, on the conservation of the environment and its sustainability. The processes try to follow the development of the multididactics of [15], based on the search for cultural and social recognition for the development and use of technology.

1.2. Scientific Skills: Cognitive Approach

Scientific skills from the cognitive approach are conceived as the set of capacities that allow the development of knowledge from empirical experience [16]. This position considers the set of stimulated competences for the search for new knowledge as a precedent of the previous knowledge that the student possesses [17, 18], when contrasting it with the results obtained when observing, analyzing, comparing, arguing, refuting and reflecting on certain processes that allow them come to knowledge. Deeper knowledge has been found in students who used technologies when performing reflective tasks through interpretation [19], as well, combinatorial thinking generates better skills when there is cooperation between members of a student group [20]. Other evidences have reported results in that the use of technology allows generating motivation, critical thinking, better opportunities [21], and reflective capacity to propose solutions to certain scientific problems.

In this case, the SEI> SST> SSR scheme is proposed, through a scientific skills development program with environmental ecology. However, there is special interest in the use of other type methodologies: I > PBL > RF [Inquiry > Problem Based Learning > Reflection and Feedback], for which the basis is the studies that sought to develop communicational and scientific informational skills in students with a low level [22, 23]. We adapt these processes to the methodological phases of the robotic ecology program: inquiry (I) to the intelligence process of social ecology or motivational process, problem-based learning (PBL) to social scientific tasks, and reflection and feedback (RF) to the phase of social scientific reflection. This allowed bringing the scientific research process closer to studies and proposals focused on recycling for social ecological awareness [1, 3]. The objective of the research was to modify the scientific abilities of a school group through the application of a robotic ecology program in its formative process.

2. Method

The research is based on the positivist paradigm, a study of an applied type with manipulation of an independent variable, and the verification of its effects on another dependent, so we carry out measurements in the quantitative approach. The design was experimental with pre- and posttest. We compared two groups of students compared methodologically ($n_{(Exp.)} = 45$; $n_{(Cont.)} = 35$). A total of 80 students from the fifth and sixth grade of primary school were included as the total of the experimental sample. The number of subjects was mostly female (*male* = 39 %; *female* = 61 %), all of whom attended educational institutions in vulnerable contexts in capital districts. The average age of the participants was 10 years, 8 months (*Fifth grade* = 10.43 years*; Sixth grade* = 11.2). Variables such as: (a) regular attendance to classes, (b) profound cognitive deficiencies, (c) age above educational level, (d) pre and post-pandemic reinforcement stages, (d) health status were controlled.

All participants gave their consent by signing the *Parental Informed Consent*. This document was prepared in accordance with the acceptance of the parents and signed by them, to integrate their children in the experiment. This was given as part of a cycle of cognitive reinforcement of the science and technology area in their respective educational institutions. The process described made it possible to avoid biases such as the institutional directive obligation or the teacher's demand. After contacting the parents, the school directors and the tutors of the corresponding classrooms were contacted, who mediated the investigation in general. This administrative procedure followed the ethical research model based on the model established by the Declaration of Helsinki; and the generation of exogenous factors that would invalidate the study was avoided

We developed a test of theoretical and practical performance on scientific skills, in which dimensions of type: (a) Knowledge, (b) Observation, (c) Reflection were measured (Table 1).

Table 1

Test-subtest correlations in the Test and Scale constructs.

Variable	Dimension	*r**
Scientific skills (SS)	Knowledge	.891
	Observation	.901
	Reflection	.789
Environmental Awareness (EA)	Awareness about the environment	.871
	Beliefs about caring	.883

Note: *p <.001.

The tasks carried out made it possible to measure the content of these dimensions through tasks called "*Scientific Situations*". The tasks were based on the research proposed by [21] and [24], choosing and diversifying the most appropriate dimensions for the students of the evaluated context. Likewise, an *Environmental Awareness Scale* was used with the intention of supporting the qualification in scientific reflection, in this case, the instrument allowed to measure the constructs: (a) Awareness about the Environment, (b) Beliefs about caring. The level of reliability achieved in both instruments was acceptable ($Ins._{(\alpha\text{-}1)} = .921$; $Ins._{(\alpha\text{-}2)} = .890$). Table 1 shows the results of correspondence between the variables and the dimensions through a correlation analysis of the principal components with the variables.

2.1. Procedure

The ecological problem of a coastal beach was addressed through a social responsibility program, this was directed in agreement with a private university and three schools from vulnerable contexts. The program consisted of three pedagogical phases [SEI - SST - SSR], running in six months of the school term. The execution of the second and third phases allowed the subjects of the experimental group to come into contact with the recycled waste to develop basic prototypes of robots, following their creativity criteria attached to the teaching routes applied by the teachers. The students in the control group only developed daily recycling.

3. Results

The initial scores for scientific skills ($t_{(53)}$ = -1,073; p >.005) and environmental awareness ($t_{(41)}$ = -1,110; p > .005) were statistically equitable (no significance). According to Figure 1, the global results allowed to find notable differences that support the improvement of scientific skills ($t\text{-}SS_{(74)}$ = -3.831; p <.005) after executing the eco-robotics program.

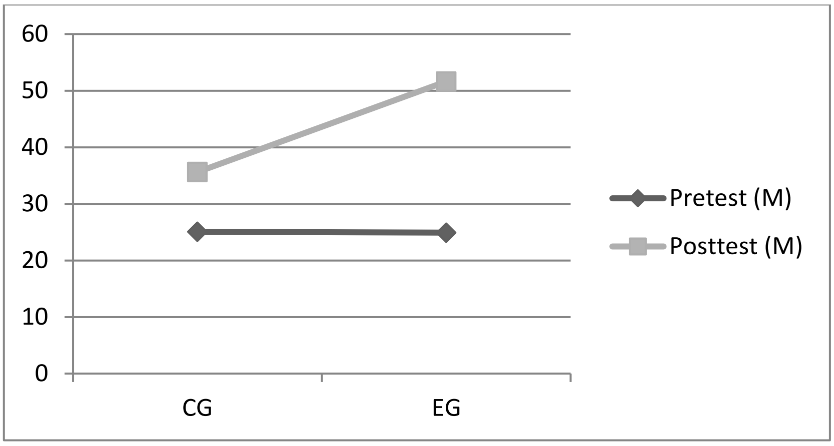

Figure 1: Pretest and posttest measurements in scientific skills

Regarding environmental awareness, the comparison of means allowed to establish considerable increases in the experimentation group (t-CA $_{(72)}$ = -2.720; p <.005), these measurements evidenced the parallel development of this construct (figure 2).

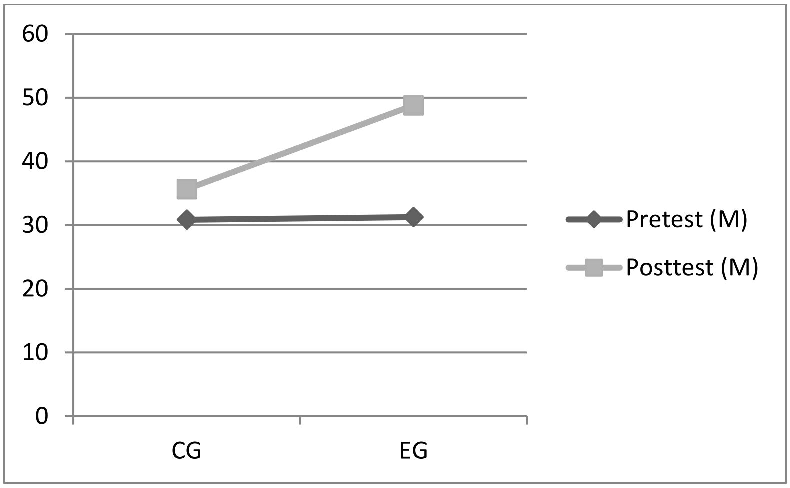

Figure 2: Pretest and posttest measurements in environmental awareness

Table 2
Average in dimensions of scientific skills and environmental awareness.

	Pretest		Posttest	
Dimension	CG	EG	CG	EG
Knowledge	10.11	10.19	15.16	16.01
Observation	9.21	9.16	15.21	18.32
Reflection	5.71	5.8	6.34	10.81
Awareness about the environment	15.20	15.01	21.30	20.41
Beliefs about caring	12.30	12.35	18.83	20.01

Note: CG = Control Group; EG = Experimental Group.

The initial scores did not show significant differences before starting the experimental approach. On the other hand, favorable scores were evidenced for the experimental group after applying the pedagogical phases [IES-TCS-RCS] of the robotic ecology program, which represented significant differences in the observation dimensions ($t_{(70)}$ = -2,45), reflection ($t_{(77)}$ = -2,31), awareness about the environment ($t_{(75)}$ = -2,21), beliefs about caring ($t_{(78)}$ = -2,10). Table 2 also describes non-significant differences in the scientific knowledge dimension ($t_{(61)}$ = -1,02).

The findings allow us to assert that the method based on responsibility with the SEI > SST > SSR, model, contributed to the strengthening of scientific skills by constantly awakening the previous knowledge obtained as in other studies [1, 11]. This prompted the students to develop robotic prototypes for the construction of scientific learning. In this sense, the program was able to integrate creativity towards scientific inquiry processes through STEAM in the experimental group as scientific feedback processes [3, 4]. Additional tests were developed to measure progress in scientific skills over the six-month period. We applied these evaluations three times during the process, although they were ad hoc tests, they served to monitor the quality of progress in each of the dimensions. It should be noted that these resembled the structure of the test in general. The first test was carried out a few weeks after the application of the pre-test, and the last, two weeks before the post-test evaluation. In figure 2 we observe better progress in knowledge ability with a better difference between the first and second evaluation (*diff*. = -5.44), and between the second and third application (*diff*. = -4.51).

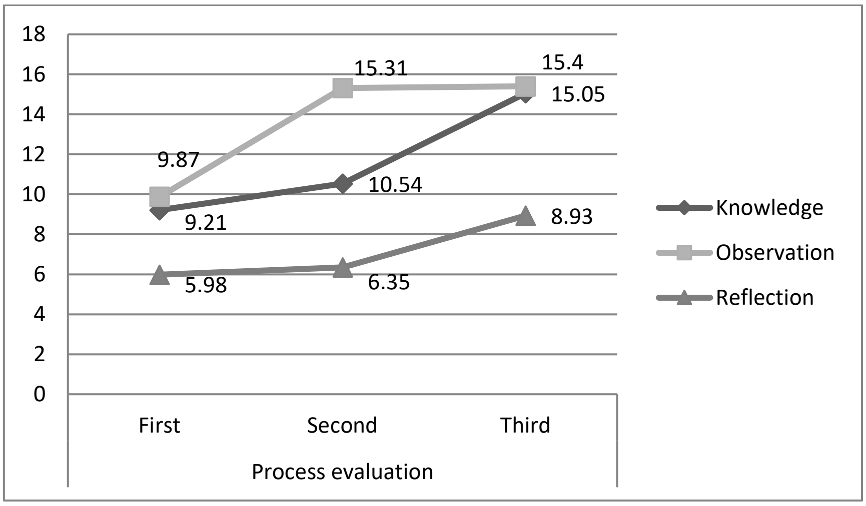

Figure 3: Pretest and posttest measurements in environmental awareness

On the other hand, the progression in the observation dimension was a little less fluid, the increase was less between the first and second reports (*diff.* = -1.33). However, from the second evaluation, evidence is reflected that supports that the property to perform basic observation was complex to develop for the test subjects (*diff.* = -0.09). Finally, less obvious progress is observed in reflective ability between the first and second evaluation. The increase becomes more pronounced in the last evaluation (*diff.* = -2.58), although the progress up to that moment (X = 8.93) is low compared to the beginning (X = 5.98).

The general approach based on the use of social ecological intelligence [13, 14], and cooperative and motivational didactic processes [20, 21] have contributed to the improvement in obtaining knowledge, increasing the elaboration and cognitive reflection. This last dimension was also evidenced when developing environmental awareness processes in parallel in the cleaning of the coastal beach.

Regarding the case of the evidence reported in progress, it is necessary to accept that the knowledge dimension is less complex to develop in students who are more used to being receptive. Some evidence has shown that as a basic ability it is usually used in subjects with certain similar characteristics [7, 10], although not entirely basic. Therefore, the expansion of individualistic work with robotics has been transformed into this experience due to the collaboration generated by the individuals themselves in their guided learning, as they also do in other contexts through cognitive collaboration [8, 9, 10, 11]. In any case, the reflective processes evaluated in the progress of reflective ability seem to be linked to the observational processes of the subjects of the experiment. Therefore, it is argued that the individual> robotics> learning experience can be crucial due to the stimulation generated in the science processes themselves [2].

Finally, although no significant differences were found in the knowledge dimension, it is important to note the parallel progress shown by both the control group and the experimental group, since both discovered the environment close to which they faced. This situation disposed them to obtain permanent information on environmental pollution and environmental settings as a strictly academic condition.

4. Conclusions

The robotic ecology experience premeditated the modification of scientific skills, developing observation and reflection in the participants of the program of boarding a coastal beach. Regarding their ways of thinking, the scientific task and social scientific reflection phases of the program improved their awareness of the environment and caring for the environment as part of student scientific reflection. The specific results showed improvement effects in scientific knowledge, although the results did not allow to show clear advances in the students of the sample.

The study helps to clarify links between science learning, lived conservation of the environment and the use of waste as a method of STEM education. It is shown that the ability to know is crucial to those of observation and reflection, although in contexts in which the use of the natural environment are issues of social (environmental) need. These last competences generate a broader conservative thought, competences for investigative analysis; and positive attitudes towards creative robotics in schooling.

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