



The Preparation of Eco-citizens in The Environmental Edu Communication Program "LemonSea Ecuador": Getting to Know the Polluted Areas of Manta City Using the Lemon Map

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Abstract. This article shows the results of a research study whose purpose was to create and implement a non-formal environmental education program that promotes the reflection of the participants based on four prioritized environmental problems of Manta city. Design Based Research was used, and 10 activities were designed based on games, simulations, and digital material. The strategies and resources of the program were implemented in three schools: public, private, and private with state-funded financial support. A total of 288 students and 17 teachers participated. Following the DBR design, a cycle of iterations was completed in each school to understand how the designed program worked in practice. The researchers' journals provided an assessment of the program. The Lemon Map activity proved to be useful in raising young people's awareness of environmental issues in a non-traditional way, students' motivation to perform experiments or manipulate tools such as Google Earth was very high. The teachers had a positive perception of the strategies and resources, especially the drone videos taken in the most polluted areas, and their effectiveness in developing eco-citizensry.

Keywords: environmental education program, design-based research, eco-citizens.

1 Introduction

1.1. The environmental education program LemonSea Ecuador.

At present, the climate emergency emphasizes the urgency of measures to reduce or stop climate change and avoid potentially irreversible environmental damage which would jeopardize the survival of the planet and those who live in it. Educating about the environment (EE environmental education) should be a priority. Knowledge of the natural environment is an interdisciplinary subject across the curriculum. From different subject matters in school, children can understand the environment they inhabit, create sensitivity to preserve ecosystems and reflect on environmental problems and make a call to action. The EPA defines environmental education as a process that

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enables people to investigate environmental issues, become involved in problem solving, and take action to improve the environment [1]. In Ibero-America, the critical approach to environmental education is understood as a dialogic process in which all school and social actors participate, inseparable from educational practice and collaborative learning processes. This approach has been widely explained in the works of various authors [2][3][4]. More recently, different authors have highlighted the need to include a political approach to EE that associates it with social change. In this line of thought, Sauve [5] understands Ecocitizenship as a way of relating to the world centered on living here together, a contextualized and situated relationship, which implies collective responsibility for the life systems - of which we are a part - and which requires competencies to be effectively inserted in the political dynamics of decision and action on socio-ecological issues. LemonSea Ecuador, the Environment Educational program presented here, includes three basic principles:

- Seeing EE as a process of dialogue and collaborative work among educational stakeholders to address environmental issues and the search for solutions [3]. Environmental knowledge is built in learning ecologies [6] that foster active, ubiquitous, multimodal, collaborative, and recursive feedback learning.
- It highlights the development of awareness, sensitivity and attitudes related to the solution of environmental problems is best developed when students are exposed to the knowledge of their immediate environment.
- EE action must be transformative, characterized by its intentionality, and its call to action [5] and to the social change(s) necessary to find solutions from democratic participation and the vision of a utopian future in which human health, social conflict resolution and equity must be paramount [7]. Based on this conceptual framework, the objective proposed by LemonSea Ecuador was to design and implement an EE program that included content and educational materials on the main environmental problems of Manta city.

1.2. The LemonSea Ecuador education and educational-communication intervention program

The purpose of "LemonSea Ecuador" is to educate in environmental issues from a critical and political perspective that builds a sense of Eco-citizenry. The project started in Manta, a port city on Ecuador's central coast. The fishing industry is of great economic importance for Ecuador. Manta's tuna industry is the economic engine of the city, but also constitutes a great source of pollution of the city's sewage through the discharge of waste from its various industrial processes. Studies by González and González [8] have demonstrated the existence of a high percentage of pollution of the city's two rivers by industrial waste by up to 60%.

Ecuador's national policy to address the adverse effects of climate change, through the document First Nationally Determined Contribution (NDC) [9] ratifies the Paris Agreement and designs the guidelines for mitigation and adaptation to the adverse effects of climate change. The "Manta Verde Plan" proposed by the city hall has identified four main environmental problems: ocean pollution, water scarcity, solid waste treatment and sewerage. LemonSea Ecuador focuses on these four main environmental problems.

2 Methods

This research study had a Design Based Research (DBR) approach. According to the Design-based Research Collective [10] DBR is an important methodology for understanding how, when, and why educational innovations work in practice. Research conducted under the DBR methodology involves a series of iterative cycles, continuous cycles of design, implementation, analysis, and redesign that lead to the refinement of the artifacts produced. In our research we have tested the contents, strategies, and resources pertaining to the environmental problems of Manta city in three educational interventions (cycles) in the three schools. The explanation of each cycle is presented in 2.2. The starting point, i.e., all the activities carried out prior to the interventions, is described below.

2.1 The starting point

Our starting point was a series of meetings with the technicians from the City Hall and the local Water Department of Manta (EPAM) since they are the institutions with direct competence on the four main environmental problems. The work team was composed of three EPAM technicians, one technician from the City Hall, seven edu-communicators from the LemonSea Ecuador Project (hereinafter "Lemon Instructors") and four expert researchers on Ecotoxicology, Ecology and Ocean Acidification. Six technical meetings and three demonstrations were held. At each meeting, discussions were held on the four prioritized environmental problems, the status of the problem, its causes, its main effects, and the national and local policies that regulate this sector. Based on this information and a compilation of published articles on Manta's environmental problems, the contents that would be shared in the interventions in the three participating schools were designed and evaluated by the team's technical staff.

2.2 Phases that make up each school intervention (The BDR cycle).

The activities carried out in each of the three intervention cycles are explained below:

- Visits to the three participating schools and establishment of documents of agreement and regulation of terms. Each school and the members of the instructional team of the LemonSea Ecuador program met and discussed the document called "Memorandum of Understanding". This document established each party's commitments and required the parties' signing off on it. As for the participation of the students, an Informed Consent document was established and signed by the students' parents.
- A first contact with the locations and their four prioritized environmental problems through a route called "Chiva verde" (explained in 3.1.). The tour was designed by one of the researchers of the technical team. Four polluted points were visited, and activities were carried out in each one to understand the type of pollution affecting each area, its causes and its effects. Water samples were taken.

- Working meeting between LemonSea Ecuador's instructional team and the students and teachers of the three schools to explain the methodology that was used during the four days of each intervention.
- Application of the Questionnaire "Initial Environmental Knowledge" to the participating students to learn about the entry level with respect to environmental information that each group of students possessed.
- Touring of each group of students through each of the ten science stations designed to learn about the city's environmental problems. Section 3.1 presents each of these science stations in detail. LemonSea's interventions in each school last 5 days. Each day the participating students spend 4 hours visiting the different LemonSea science stations. It is expected that at the end of the intervention each student will have enjoyed each of the 10 stations designed.
- Each day, the Lemon Instructors wrote a journal entry on their perception of the program, its resources and effectiveness in achieving the objective.
- On the 5th day of the intervention, a meeting was held with teachers and school administrators to gather their impressions of the program, its strengths, and weaknesses.
- One month after the end of the intervention, a visit was made to the participating schools to collect the environmental products created by the students and donated material is delivered.

2.3 Schools and students participating in interventions.

A multiple case study design was used [11]. The case study is the study of the particularity and complexity of a singular case, to understand its activity in important circumstances [11]. The schools were chosen using convenience sampling. A public call for participation was made and the schools that met the following characteristics were selected:

- Having carried out innovative projects involving the participation of students and teachers.
- Commitment of school administrators to support educational projects proposed by students and evaluated as viable.
- Having one type of educational institutions in the country: public, private, and private with state-funded financial support.

Table 1 summarizes the characteristics of the schools.

Table 1. Characteristics of the three schools involved in the Lemon Sea EC Environmental Education Program

School 1: Private School		
Teachers	Students	Spaces and resources available for intervention
3	100 52 females 48 males	Audiovisual room Auditorium with AC, Internet, and Projector. Chemistry Laboratory Roofed area 1

		Roofed area 2 Multiple purposes court. Students can use cellphones two hours per day.
School 2: Public School		
Teachers	Students	Spaces and resources available for intervention
6	100 51 females 49 males	Playground Multiple purposes court 4 classrooms 30 tablets donated by Project Movistar
School 3: private with state-funded financial support		
Teachers	Students	Spaces and resources available for intervention
8	88 50 females 38 males	Auditorium with AC, Internet, and Projector. Roofed area 1 Roofed area 2 Multiple purposes court 2 classrooms

The students participating in the environmental education program were in 8th, 9th and 10th grade or 1st and 2nd year of high school. Their ages ranged from 14 to 18 years, with an average of 15.3 years. The students were selected by the principals and teachers at each school according to the criteria established by the researchers: students between 14 and 18 years of age, with a gender ratio of 51% female and 49% male, since this is the current population distribution in the country. The students worked collaboratively in groups of 8 to 10 students each. In two of the centers involved, 10 teams of 10 students each were formed, and in only one of the centers 10 teams of 8 students each were formed. Another important aspect was that the school principals of the schools were asked to respect the natural groupings that the center already had when establishing the 10 groups of students that would go through the 10 science stations.

The participation of teachers was conditioned by the dynamics of each school. For example, in the public school there was greater flexibility so that teachers could leave their regular activities and dedicate themselves to accompanying the Lemon Sea Instructors, while in the private school there was little teacher participation. The school management selected from among the group of STEM teachers those who would be participating with the students. An important aspect in this regard was that the STEM teachers from the schools involved lacked specific training in STEM teaching and in some cases in the city's own environmental problems with a more in-depth approach.

2.4 Instruments and techniques used.

The Researcher's journal was used for the collection of information during the implementation of the interventions. The teacher's journal is a qualitative tool that aims to capture through the teacher's narrative the moment of the intervention of the educational program. In this case, the teacher's journal consisted of daily notes made by the seven LemonSea Teachers at the end of each day at the school. About eight pages of notes were collected for each intervention. The characteristic narrative of the journal is using the first-person voice. The diaries were processed using classical methods of qualitative data reduction.

3 Results

The research conducted under DBR methodology involved a series of iterative cycles that gave rise to different products and results. The first result of this research was the Ecuadorian LemonSea Environmental Edu-communication Program. Therefore, we begin the presentation of results by explaining the learning ecology designed to educate school teenagers about the main environmental problems in Manta city. Then, we analyzed the results of the researcher's narratives via journaling.

3.1 Towards an environmental learning ecology: The scientific stations of the LemonSea Ecuador Environmental Program

The LemonSea Ecuador program conceives teaching in STEM areas from the notion of learning ecologies [5]. Our learning ecology is composed of 10 science stations through which students develop environmental knowledge and the attitudes and sensibilities that empower calls to action. Each of the stations includes an objective, learning strategies, educational resources, and assessment. Table 2 shows the name and objective of each of the ten science stations of the project:

Table 2. The ten LemonSea science stations.

Science Station	Objectives
Lemon map	Developing awareness of the polluted areas in Manta and the economic and social dynamics present in it. Based on this knowledge, proposing actions to rethink and imagine a different city.
Lemon Oil	Recognizing through an experiment, the effects of oil pollution in water.
Lemon Sea	Understanding ocean acidification and its effects on the life of marine ecosystems, as well as the implications of this issue on the economic life of Manta city.
Lemon Air	Analyzing how air pollution occurs by conducting an experiment.
Super Plastic	Analyzing the problem of plastic waste and quantifying the amount of waste generated in the school daily to generate ideas that contribute to new ways of responsible consumption.
LemonTokers	Developing environmental activism practices in digital environments through the production of environment-related content on the main pollution problems of Manta city in audiovisual format.
Lemon Selfie	Motivating the participation of female students in STEM disciplines through talks about the environment with female scientists in the city. The memories of the meetings are recreated as images that are posted on the students' social networks.
Lemon Clean	Reusing vegetable cooking oil to produce handmade soaps that are later used in the schools involved.

Imagine Manta	Reflecting on the concept of sustainable city, recreating the dreamed city in an audiovisual way, and proposing strategies to make this aspiration feasible.
Lemon Project	Designing school environmental projects to transform school spaces and practices towards sustainable models.

The Lemon Map station for the recognition of the territory and its problems: strategies.

Strategy # 1: Initial environmental knowledge test on the city's environmental problems

To determine the level of prior knowledge of the students, a questionnaire was designed with 8 closed questions and 2 open questions related to the four prioritized environmental problems. The application of the initial questionnaire on environmental knowledge of the surroundings revealed the students' lack of knowledge regarding the territory where they live.

Strategy # 2: A tour of four highly polluted areas in Manta city to identify the main problems.

This tour is called *La Chiva Verde* (the Green Party Bus) and consists of an ecological tour on a vehicle typical of the city's festive activities with the purpose of recognizing the four main locations of pollution in Manta city. At each point, environmental experts explain to the teachers the type of pollution, its causes and effects, and samples of contaminated seawater are taken. At the end of the tour, the samples are compared, and conclusions are drawn.

Strategy # 3: Demonstration of the city's wastewater system by a technician from the Water Department using GoogleEarth®.

EPAM technicians participate in this activity and use a previously designed 3D *GoogleEarth®* tour to explain the city's drinking water and wastewater system.

Strategy # 4: Reflective viewing of videos taken with drone of the relationship between ocean pollution on the coast of Manta city and fishing production activity.

During *La Chiva Verde*, aerial shots of the most polluted areas of the city's coast are taken by drones which show clandestine pipes from the industries that dump waste into the rivers and the sea. It also shows the diesel fuel dumped by the fishing boats in the port area. These videos are watched by the students together with the LemonSea Instructors who explain and elaborate on the details of what is observed. There is a script of questions to encourage discussion.



Fig. 1. Students were watching video drones.

Strategy # 5: Identification on an enlarged map of the polluted areas of the city and use different colors to indicate the highest degree of pollution.

It is a giant poster that reproduces the map of the city. Stickers in 3 colors are used to locate the problem areas from those with the highest degree of pollution (red color), the intermediate ones (yellow color) and the less polluted ones (green). By engaging in the previous activities, students develop the ability to identify on the map the polluted areas and highlight the degree of pollution present.



Fig. 2. Students located the polluted areas on the city map.

Strategy # 6: Wall Mural “Ciudad Soñada” [Dream City].

Flipchart paper, colors, seeds, and recycled material are used by the students to create drawings that recreate the city they want to have. They add a caption that represents their commitment to the city. These drawings are shared on a wall that the school sets aside for the mural.



Fig. 3. The dream city gallery.

3.2 The perceptions of the teachers.

In the researcher's journal, teachers seem to be satisfied with the outcome of the intervention. The researcher's journal can read "Today we finished the intervention. This last session was very emotional. The boys and girls wanted to comment on the experience. They said that this week was a lot of fun and that they wished to have more activities. They wanted to learn in the schoolyard doing experiments, or in the audiovisual room with GoogleEarth® and the drone videos. They asked when we will be back and asked us to talk to the teachers to get them out of the classroom" (Woman, 55 years old, teacher). Another researcher from the team of teachers noted that "The motivation of the kids was incredible. Even though I think the days were quite long, especially after morning recess, they were still motivated, they asked questions, manipulated the materials, expressed their dream city through drawings where they expressed great creativity" (Male, 29 years old, teacher). "When we started the intervention (especially on day 1), we noticed that the way the school handles discipline affects the activity to a certain extent. For example, the students do not dare to manipulate the tablets or the Lemon Instructor computer to access the geosatellite representation. Today was day 2 and the students tried to locate their house, the main rivers, and the polluted areas on the map; they checked curiously the 3D representation to learn where the drinking water they consume in their homes comes from. The video drones are a powerful tool" (Woman, 23 years old, edu-communicator).

One aspect that called the attention of the three researchers in their journal was that although they were aware of the responsibility they have regarding the garbage that pollutes the rivers and the sea, there is little or almost no reflection on responsible consumption habits, on the role of industry. "I am very struck by the fact that when discussing why so many vacant areas of the city are used as garbage dumps, the offered solutions almost always end up being recycling initiatives. He mentioned that they know people they call "recyclers" and believe there should be many more, but they don't go so far as to question individual responsibility for recycling processes or the relationship of the garbage problem to consumption habits. I use the example of the fashion industry to encourage the debate on responsible consumption habits and I am surprised that two girls intervene, saying that the meat industry causes more pollution, and because of that they became vegetarians" (Woman, 33 years old, teacher).

Regarding the acquisition of knowledge by the students, the design of the Lemon Map station was aimed at orienting the recognition of the environment. The researcher's journal reads "...they seemed really surprised by the drone videos or the 3D representations of the city's bodies of water. The questions they asked showed a general lack of knowledge of the 4 prioritized problems. However, on the last day, when we evaluated the knowledge achieved through small questions, the students were able to identify the city's rivers, their location, and the causes of their contamination. Similarly, with respect to the wastewater system, they recognized the impact of local industry in the discharge of wastewater into rivers and the sea and were able to identify the pollution of the sea by diesel" (Male, 24 years old, edu-communicator). Another journal entry stated: "The ocean acidification aspect probably still needs to be reinforced. They were able to define the problem, but not the origin of the problems, nor were the personal actions that could contribute to solving it" (Woman, 55, teacher).

Lastly, another very important aspect of the LemonSea program design was that using active learning strategies such as games, simulations or hands-on activities can enhance the development of creativity. The diary confirms the perception of the Lemon Instructor "These students were really very motivated, and they used all their creativity into the Imaginary City Mural. Some students had prepared very elaborate and creative drawings. When they were sitting in the courtyard expressing their creativity through the drawings, it seemed that they were very relaxed and the work flowed better" (Male, 24 years old, edu-communicator).

4 Conclusions

At the end of the three planned environmental education interventions, some important findings can be identified. First, the students' knowledge of environmental issues is scarce. From the initial questionnaire, students did not know aspects such as knowledge of the wastewater system or even the fact that the city has no freshwater sources capable of meeting the local demand. The researcher's journal provided many references on the students' shocks when they saw the water flow of the city's rivers in the three-dimensional representation. Although they were aware of the existence of environmental problems in the city, they could not specify the type of problem, the causes, or the effects on the population, health, the economy, etc.

At the level of reflective thinking, some of the students' thoughts related to the logic of the market were quite well established. So, when they commented on the serious pollution problems that the local tuna industry generates, many of them expressed that due to its role in the local economy it was difficult to establish sanctions. However, another group of the students, especially the older ones, proposed using social networks to position the public discussion, especially because in the same activity they could see that the local media do not have environmental issues on their agenda. Similarly at the level of ethical discussion, democratic participation and environmental activism initially was not an option to the students; however, as the intervention progressed, they proposed more "calls to action".

Regarding the characteristics of the scientific station, Lemon Map proved to be an interesting and fun activity for the students. On the one hand, the activity brought to the school technicians who are part of the environmental departments of the municipality and these officials were quite motivated to share official information of great interest with us. On the other hand, the combination of strategies used revealed the ubiquity of these times. They learned outside the school in *La Chiva Verde*, in natural spaces, and this allowed them to experience this reality in first person. In fact, they commented that they had never been to these areas and even commented that they felt like two different cities and that they wanted to return there with their families to teach them about these issues.

The use of audiovisual media to produce messages for social networks was another opportunity to reaffirm that the language of social networks is their own, and therefore, with great agility and success, they recorded environmental messages that were then shared on the official social network profiles of the project.

Digital tools such as GoogleEarth® and the videos taken with a drones complemented the teacher's explanations to help them locate two very important representations for the recognition of the territory: the city's drinking water system and the sewage system. They were then able to locate on the map their homes, the school, the most polluted points, etc.

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