ANALYSIS OF THE DEVELOPMENT OF ENVIRONMENTAL CULTURE AND MATHEMATICAL SKILLS FOR SOLID WASTE MANAGEMENT IN SCHOOLS

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ABSTRACT

Objective: Contribute to the development of environmental awareness in the face of the global problem related to the inadequate management of solid waste; This is promoted within a didactic process that takes place in the relationship between the areas of mathematics in a communication environment and the area of natural sciences and environmental education.

Theoretical Framework: Based on the criteria of “environmental education”, “mathematics”, “communication” and “solid waste”; Since the relationship between them and solid waste benefits the comprehensive management of urban solid waste (MSW), by promoting solid waste management, this proposal was focused on educational aspects.

Method: A qualitative approach is used through emerging categories, characterizing the development of environmental awareness and mathematical communication competence. The action research method was implemented as a dialectical instrument between knowledge and practice where its articulating axis is a socio-environmental problem.

Results and Discussion: As a result, the described intervention guide was applied, there is a central task called “The production of solid waste per capita (PPC)”. This task included the most important aspects of the mathematics learning activity within the intervention guide.

Implications of the Research: Research shows that there are models and training methods in environmental management issues and mathematics teaching methods, but little in the articulation of the two disciplines for practical teaching that generates development in the integral management of solid waste; as well as little state or private investment in these issues, as it does not generate economic benefits.

Originality/Value: This study contributes to a literature that clearly shows how natural sciences and mathematics integrate to contribute to better solid waste management, generating awareness and environmental culture to impact sustainability.

Keywords: Environmental Awareness, Solid Waste, Mathematics to Communicate, Environmental Dimension.

ANÁLISE DO DESENVOLVIMENTO DA CULTURA AMBIENTAL E DE COMPETÊNCIAS MATEMÁTICAS PARA A GESTÃO DE RESIDUOS SÓLIDOS NAS ESCOLAS

RESUMO

Objetivo: Contribuir para o desenvolvimento da consciência ambiental face ao problema global relacionado com a gestão inadequada de resíduos sólidos; Isto é promovido dentro de um processo didático que se dá na relação das áreas da matemática em ambiente de comunicação e da área das ciências naturais e da educação ambienta.

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Analysis of the Development of Environmental Culture and Mathematical Skills for Solid Waste Management in Schools

Referential Teórico: Baseia-se nos critérios de “educação ambiental”, “matemática”, “comunicação” e “resíduos sólidos”; já que a relação entre eles e os resíduos sólidos beneficia o gestão integral de resíduos sólidos urbanos (RSU), ao promover uma gestão de resíduos sólidos, esta proposta foi focada nos aspectos educacionais.

Método: É utilizada uma abordagem qualitativa através de categorias emergentes, com a caracterização do desenvolvimento da consciência ambiental e da competência matemática comunicar. O método de pesquisa-ação foi implementado como instrumento dialético entre conhecimento e prática onde seu eixo articulador é um problema socioambiental.

Resultados e Discussão: Como resultado, foi aplicado o guia de intervenção descrito, existe uma tarefa central denominada “A produção de resíduos sólidos per capita (PPC)”. Esta tarefa incluiu os aspectos mais importantes da atividade de aprendizagem matemática dentro do guia de intervenção.

Implicações da Pesquisa: Pesquisas mostram que existem modelos e métodos de formação em questões de gestão ambiental e métodos de ensino de matemática, mas pouco na articulação das duas disciplinas para o ensino prático que gere desenvolvimento na gestão integral de resíduos sólidos; bem como pouco investimento estatal ou privado nestas questões, uma vez que não gera benefícios econômicos.

Originalidade/Valor: Este estudo contribui para uma literatura que mostra claramente como as ciências naturais e a matemática se integram para contribuir para a melhor gestão dos resíduos sólidos, gerando consciência e cultura ambiental para que impacte a sustentabilidade.

Palavras-chave: Consciência Ambiental, Resíduos Sólidos, Matemática Comunicar, Dimensão Ambiental.
1 INTRODUCTION

The global environmental problem is a situation in which various aspects of the contexts in which human beings have influence converge. This problem is linked to the ecological crisis, global warming and the deterioration of environmental systems. Thus, Sauvé (2005) specifies that much of this reality is due to the ways in which man interacts with the environment. These human interactions give rise to problems affecting the environment, such as solid waste, its excessive production, its inadequate management and the culture of consumerism, among others. The daily production of these pollutes the environment in various ways, i.e. rivers, air, soil and groundwater. In this regard, Sáenz and Urdaneta (2014) indicate that ‘waste generation rates per inhabitant continue to increase, reflecting the lack of awareness among citizens about how their consumption patterns influence the volume of waste generated’.

In the educational institution, and in the community in general, the problem of solid waste has a great influence given its sociodemographic and geographical configuration. The population is vulnerable, with few resources and considerable social decomposition. In order to mitigate the effects of this environmental problem, it is necessary to generate institutional pedagogical processes that contribute to stimulating environmental awareness.

In this perspective, the research project was an effort in this direction, since it had the objective to contribute to the stimulation of environmental awareness within a didactic process that takes place in the interdisciplinary relationship between the areas of mathematics in a communication environment and the area of natural sciences and environmental education having the proper management of solid waste as a transversal axis. It should be pointed out that this didactic process made it possible to link essential elements for learning, such as thinking, reflection, knowledge, action and communication, characteristics that were immersed in Paulo Freire's problematizing pedagogy.

It should be noted that the project had a direct action in the transformation of habits and behaviors of students and their families; with regard to the management of solid waste generated in the residences, from the regulatory knowledge and reflection on the environmental impact they generate, seeking the training of students committed to the preservation and care of the environment, through the efficient management of solid waste.

As mentioned earlier, the educational proposal was constructed from the interdisciplinary relationship between the areas of mathematics and natural sciences and environmental education. Within mathematical education, the proposal was to develop mathematical skills and the very
competence of "communicating". Similarly, in the environmental dimension, an appropriate solid waste management program has been used as a cross-cutting axis.

Regarding the characterization of communicative competence and the development of environmental awareness, the Priori Theoretical Model (MTAP) proposed by García et al. was adapted. (2013). and tool used by Acebal (2010) in his doctoral thesis; within the process, aspects of human development proposed in the MTAP were unified, such as the affective and action tendency with the dimensions of environmental consciousness, namely, conactive, affective and active. As to the cognitive aspect, in mathematics, it was approached from participation, negotiation and discursive activity; these associated with the curricular elements of the discipline. The cognitive dimension of environmental awareness was raised from the identification, understanding and conceptualization, in relation to the consequences of human actions on the environment and the theoretical and regulatory aspects of the proper management of solid waste.

Figure 1 sets out the interdisciplinary connections that were taken into consideration for the construction of the educational strategy.

**Figure 1**

*Components of the educational strategy*
2 METHODOLOGICAL PATHWAY

The qualitative approach of research was used as a methodological delimitation in the sense that categories arise in the process of characterizing the development of environmental awareness and the mathematical competence to communicate. The research-action method has been implemented as a dialectical instrument between knowledge and practice where its articulating axis is a socio-environmental problem; according to Cabrera (2017), this allows the "transformation of reality through questioning, reflective and contextualized activities that articulate theory and practice, knowledge and action".

The research was carried out with 35 students of the eleventh year of the Amazonian Agroecological Educational Institution Buinaima of Florencia Caquetá, it was first developed identifying the elements a priori of the current state of the thematic concern of the research from two main categories: knowledge concerning the technical aspects of solid waste and the pedagogical and formative character of the project in terms of the development of environmental awareness. Likewise, the current state of the students' management of solid waste in their homes has been characterized.

Subsequently, an awareness process was carried out on the importance of proper management of solid waste for care of the environment; This occurred in two scenarios: the first, from an in-person space with the students, which, in turn, was divided into two moments: the first, relating to the delivery of the equipment necessary for the collection and classification of their solid waste, and, a second, intended to present resolution 2.184 of (2019) referring to the technical aspects of the process of solid waste treatment in general and separation at source. The second scenario was developed virtually through synchronous meetings where conversations were held about the problem from the knowledge and feelings of our students.

To conclude, the characterization of the incentive to environmental awareness, a classroom intervention guide was developed as a didactic resource of an interdisciplinary nature between the areas of mathematics in an environment of communicational competence and natural sciences and environmental education that is done as a document adviser. It should be noted that the guide was designed taking into account the following components: The basic standards of competences in mathematics, The reference matrix in the area of mathematics, The basic standards of competences in natural sciences and environmental education, the a priori theoretical model of mathematical competences and interdisciplinary composition of learning.

It should be noted that for the characterization of the development of environmental awareness and mathematical competence to communicate, the information obtained in the...
virtual conversations and videos of presentations were triangulated, these were carried out with families; about the new color code and the importance of care for the environment and the activities presented according to the tasks proposed in the intervention guide.

3 RESULTS ANALYSIS

Within the intervention guide described there is a central task called "The generation of solid waste per capita (PPP)". This task includes the most important aspects of the mathematical learning activity within the intervention guide. Likewise, it includes an element of environmental education with the aim of demonstrating the importance of mathematics lessons for solving real environmental problems.

This task contains four demands, three of which are typical of mathematical education and one of environmental education. These demands are listed below:

- given the capacity register control, design a strategy to calculate your own PPC in your home;
- compare your PPC with the theoretical value given in Florencia Caquetá’s PGIRS. Represent your results;
- based on this comparison, are you contributing to or affecting the measurement of this index in your community?

3.1 SHARE AND DISCUSS THE RESULTS WITH YOUR COLLEAGUES

The starting point for the creation of the mathematical communication environment was the collection of data. Compliance with this criterion occurs in the registration of capacity control of waste generated in the residences. Just over 90% of students successfully completed the exercise. They were meticulous with the information, recorded day after day demonstrating their scientific spirit. It is important to point out that, although teachers provided a guide table for registration, there were students who developed their own instruments to accomplish the task.

As for the first demand, the mathematical learning activity performed by the students presented a common heuristic in their development with some variations in the representation and numerical calculations presented. Figure 2 outlines this heuristic:
For the first two aspects mentioned, the learning activity presented by students E6, E15 and E28 was analyzed.

As for obtaining and presenting the data, E6 uses a tabular representation whose first row lists the cardinal number of the weeks in which the capacity control was performed and in the second row the amount, in kg, of solid waste generated in that time period. The quantity considered is the mass of solid waste (commonly called "weight") and its measurement is in kilograms. E6 makes the total sum of four weeks, that is, the eight capacities. It is noted that the sum presents calculation error, because the correct value is 71.4 kg.

The corresponding mathematical activity of the E15 student is shown in the following figure:
E15 presents its data through graphical representation; a histogram that relates on the horizontal axis the weeks of capacity and the amount of waste generated in it. This representation has the advantage of presenting the amount of waste for the eight volumes considered for a better visualization and understanding of the process carried out in the residences. For the summation (partial) of the amount of waste generated, E15 is performed within the calculation of the arithmetic mean, therefore its analysis is not yet presented.

The third student E28 presents the following learning activity in these two strands:

The E28 student used a tabular representation, such as the E6 student, with the particularity of registering the two capacities per week by performing partial sums. Finally, make a total sum corresponding to the capacity of the four weeks.

The mathematical activity of the E6 student consisted in using the splitting algorithm to obtain the daily average waste generation.
Figure 6

Mathematical learning activity of the student E6 (Calculation of the arithmetic mean (average)).

![Image of E6's work]

It is important to note that E6 has correct numerical calculations, and also has an adjacent label on the content of which an appropriate conceptualization on the arithmetic mean can be determined.

In this part of the mathematical learning activity, the E15 student treated the data differently from his colleagues, as he did not obtain a total sum to obtain the average; on the contrary, he obtained partial sums per week to obtain also weekly averages per day of solid waste generation. Finally, calculate the overall average by summing these partial averages and establishing a quotient over four, which corresponds to the number of weeks of capacity.

Figure 7

Mathematical learning activity of the student E15 (Calculation of the arithmetic mean (average)).

![Image of E15's work]

Although it is an unusual heuristic, it is still valid and shows that the diversity of thought processes should be part of didactic analysis in mathematics classes.

The student E28, like E6, made use of the dividing algorithm and presented a label highlighting the conceptualization associated with his numerical calculus.
Figure 8

Mathematical learning activity for students E28 (Calculation of the arithmetic mean (average)).

For this last part of the mathematical learning activity, which consists in obtaining the PPC from each of the households, the E6 student qualitatively presents that five people live in their family nucleus, therefore justifies their calculation appropriately.

Figure 9

E6 Student Mathematical Learning Activity (PPC Calculation).

As for student E15, although he does not discuss the number of inhabitants residing in his house verbally or in writing, his presentation suggests that the number of inhabitants is seven and makes a calculation.

Figure 10

E15 Student Mathematical Learning Activity (PPC Calculation).

The E28 student uses a label whose caption brings the calculation of their PPC. In the same way as the previous pupil, he does not put forward any argument as to the number of inhabitants of his nucleus, although it is clear that this is deducted.
In a second demand, the guide incorporated a theoretical reference value for the PPC of the city of Florence. The objective was to relate the activity of mathematical learning, the experience in the real context and the contribution (or loss) of the students to the care of the environment.

**Cognitive demand 2:** Compare your PPC with the theoretical value given in Florencia Caquetá’s PGIRS. Represent your results. The E6 student used a graphical representation, using a histogram that compares his homemade PPC to the theoretical PPC.

Likewise, he presented conventions that allow a correct reading of his activity; in turn, the student E15 uses a graphical representation, using labeled circles (Florence, house) that contain both compared values and establishing an order relation through the sign $>$ (greater than).
Figure 13
Mathematical learning activity of the student E15 (Comparison of calculated and theoretical PPC).

The student E28 used an iconic representation, in which, by comparison of size, he appropriately tried to give a connotation that his calculated PPC is superior to Florence's theoretical PPC.

Figure 14
Mathematical learning activity of the student E28 (Comparison of calculated and theoretical PPC).

3.2 IMPORTANCE OF CLASSROOM PRACTICE IN RELATION TO ENVIRONMENTAL AWARENESS

The mathematical learning activity was articulated in such a way as to contribute to the promotion of environmental awareness. Below are some results of the activity developed by the students; For this analysis was transcribed an audiovisual instrument that contains the interaction of students and teachers in the virtual link described for this task. Below are some of the student's lines that were considered relevant to this study.
Table 1

*Students' considerations regarding the development of environmental awareness.*

- E15: En mi casa nos parece bueno la separación de los residuos sólidos porque ayudamos a cuidar el medio ambiente ya que los recicladores aprovechan para sacar el material reciclable y no terminan en los rellenos sanitarios además profe si no hacemos algo seguiremos matando el planeta.

- E13: Profe uno habla de cuidar el medio ambiente y todo eso, pero en realidad hacemos todo lo contrario; como por ejemplo mi mamá me dice cuide al agua, no la malgaste que se está acabando; pero cuando vamos al río, tiramos los botellas, deje el plástico y la basura donde estemos. Que día se colocó trawa conmigo, porque le dije que estamos separando los residuos sólidos en casa para ayudar con el medio ambiente y venimos al río y lo contaminamos.

- E8: Acá en la casa con mi mamá y mis hermanos estamos tratando de utilizar menos plástico y haciendo la separación de los residuos sólidos, juguetes, pero mi padrastro es un gallo, no colabora, dice que unos pocos no hacen nada que eso no sirve para nada, que mientras nosotros estamos separando todas las demás personas están tirando la basura donde caga, pero bueno poco a poco nos está ayudando.

Figure 15

*Environmental recreational activity referred to. (E16, E32, E18, E1)*

3.3 CHARACTERIZATION OF MATHEMATICAL COMPETENCE, COMMUNICATION AND ENVIRONMENTAL AWARENESS

As mentioned above, a matrix developed by García et al, 2013 and Acebal 2010 respectively has been adapted to characterize mathematical competence, communication and environmental awareness. This matrix is presented below with their respective results in the scope of the learning activity.
Table 2

Characterization of mathematical competence to communicate in the context of environmental problems

<table>
<thead>
<tr>
<th>Competence Communicate</th>
<th>Human Development Aspects</th>
<th>Sub-Processes</th>
<th>Learning</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialogical process through which one participates in the construction and negotiation of meanings to strengthen a mathematical discourse that allows one to approach the solution of contextual problems.</td>
<td>ACTION TREND</td>
<td>DISCURSIVE ACTIVITY</td>
<td>It understands and transforms information, quantitative and qualitative, extracted from situations of daily life and the environment that allow it to approach knowledge as a natural scientist.</td>
<td>Record your observations and results using diagrams, graphs, and tables.</td>
</tr>
<tr>
<td></td>
<td>AFFECTIVE</td>
<td>NEOTNATIONS</td>
<td></td>
<td>Transforms the representation of one or more information</td>
</tr>
<tr>
<td></td>
<td>COGNITIVE</td>
<td>PARTICIPATION</td>
<td>It justifies or refutes, orally and in writing, inferences based on quantitative information for the construction of strategies that lead to innovative solutions in the development of personal and social commitments.</td>
<td>Provides statements that support or refute an interpretation of the information available in the context of problem resolution.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Draws plans to solve problems involving quantitative or schematic information.</td>
</tr>
</tbody>
</table>

Source: extracted and adapted by García et al. (2013)

Table 3

Indicators of categories of dimensions of environmental awareness

<table>
<thead>
<tr>
<th>Environmental awareness</th>
<th>Dimensions</th>
<th>Categories</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>System of experiences, knowledge and experiences that the individual actively uses in his relationship with the environment (Alea, 2006, cited by Acebal, 2010)</td>
<td>COGNITIVE</td>
<td>Identification of theoretical aspects of environmental problems</td>
<td>Understanding PPC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Identification and understanding of the causes and consequences of human actions on the environment</td>
<td>Possible causes of the degree of contamination in a given setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptualizes aspects of proper solid waste management.</td>
<td>Consequences of own actions due to waste generation on quality of life.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process of separation and recycling at source and knowledge of resolution 2,184 of 2019 (new color code)</td>
<td>Definition of solid waste</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Solid waste generation and identification of ecological points.</td>
<td></td>
</tr>
</tbody>
</table>

Source: withdrawn and adapted from Acebal (2010)
By making an analytical synthesis of this characterization, one can state that semiotic representations constitute a central element in the environment of mathematical communication. It is through systems of representation that students can communicate their ideas, positions, considerations and so on. It was found that, for the most part, a system of graphical representation (bar diagram) typical of descriptive statistics was used. Thus, a second moment was presented in the task on the per capita production of solid waste; the demand was to represent, on a comparison criterion, the PPP of their residences and the PPP of the city. For this search there were varied depictions, although most were graphic and iconic. The activity has been completed in full.

All the tasks contained a demand for mathematical communication. As indicated above, the communication process, inherent to any didactic process, occurred from the articulation between the environmental dimension of the area of natural sciences and the area of mathematics. It should be noted that the students fully met the requirements in which they had to give account of the requested mathematical processes, represented adequately; however, when communicating their ideas, plans and strategies, they focused on the environmental dimension. 60% of students used numerical information to argue their proposals.

As for the promotion of environmental awareness, it was clear that students generally understood the problem and its socio-environmental implications associated with the PPP. In the presentation of the alternatives, some students noted the importance of reducing the PPP of households to contribute to the mitigation of this problem. Based on the mathematical communication environment and the task of producing waste per capita, it was understood by the majority of pupils that the increase in the index is contributing to the detriment of the environment and therefore a priority source of pollution.

There was excellent acceptance of the proposal by the community. The implementation of the proposed activities was almost unanimous and it was satisfactory for the researchers to see the evidence from the parents and the community in general in the development of the project.

4 CONCLUSIONS

Given the current state of play in the implementation of the proposal, it was generally clear that pupils had a superficial knowledge of the elements that make up the problem of solid waste. They understood the need for adequate separation at source, but not how to do it and, to a lesser extent, knowledge about the technical standard that governs it at national
level. As far as environmental awareness is concerned, it is noted that they recognize the problem and its consequences, as well as the assertion that this is largely due to man's interaction with his environment.

In the theoretical perspective of research, the common aspects between mathematical education and environmental education were identified from the curricular and didactic perspectives that allowed for the interdisciplinary integration between them. Thus, interdisciplinarity becomes an opportunity to address several problems from the identification of curricular connecting points, assuming the conceptual structures of science as emerging categories of student activity and not as content decontextualized and without pragmatic meaning.

The encouragement of environmental awareness is not a pedagogical component exclusive to the area of natural sciences. It is the obligation and responsibility of all areas of the school curriculum to implement actions aimed at mitigating the effects of the environmental crisis materialized in the constant climate changes, water pollution, among other problems; and it is through a solid environmental awareness that educational institutions can contribute to qualifying human actions for the preservation of the environment. Once the process was concluded, a change in the mental structures of the students became evident, related to the tendency to take care of the environment and to propose alternatives that lead to the integration of the community in these initiatives.

In relation to students' mathematical activity, it can be stated that it is possible to diversify practices in the classroom so that the emerging knowledge is meaningful, to the extent that the didactic inputs are problematic in the student's environment; this allows this knowledge to transcend the classroom and make sense in the student's reality. Likewise, with the implementation of these types of proposals, it is possible to widen the students' perspective as to interaction with their environment and to generate responsible actions which contribute to its preservation.

5 RECOMMENDATIONS

The research project was carried out from the family context, linking all its members in the development of environmental awareness, which made it possible to transcend face-to-face education; in this perspective, it is recommended to build learning environments that promote family participation in the construction of knowledge and in changing attitudes, in relation to care for the environment. As well as linking the curricular drawings of each of the areas of
knowledge of the Amazonian Agro-ecological Educational Institution Buinaima with the processes of environmental awareness generation through the dimensions: cognitive, conative, active and affective.

Similarly, it is proposed to link the high school grades of the educational institution in the process of separation, classification and recovery of solid waste generated in the institution and their respective households. In addition, social service project (MEN Resolution 4.210 of September 12, 1996) with the development of environmental awareness in elementary school children.

In relation to the processes developed in the area of mathematics, it was observed greater commitment and appropriation of the knowledge of this discipline, which indicates that the mathematical competences should be mobilized through real contextual situations, which bind the student in the research processes, promoting critical reflection and significant learning.

ACKNOWLEDGEMENTS

We thank GOD Our Lord and the secondary education institutions and the Cooperative University of Colombia for the development of the master's degree and this research.

REFERENCES


