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Educación en biodiversidad y cambio climático como práctica pedagógica ante riesgos por fenómenos hidrometeorológicos e impactos socioambientales

Education on biodiversity and climate change as a pedagogical practice in the face of risks from hydrometeorological phenomena and socio-environmental impacts

Educação em biodiversidade e mudança climática como prática pedagógica diante dos riscos por fenômenos hidrometeorológicos e impactos socioambientais

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Resumen

La educación sobre la biodiversidad y el cambio climático constituye un desafío educativo de gran magnitud. El objetivo de esta investigación fue determinar los conocimientos, actitudes y aprendizajes de estudiantes del Colegio de Educación Profesional Técnica, plantel Acapulco I, sobre la biodiversidad y su influencia en el cambio climático, así como los riesgos y vulnerabilidades por fenómenos hidrometeorológicos. El estudio tiene un enfoque cuantitativo con alcance descriptivo, de tipo transversal. El análisis se realizó en torno a dos dimensiones: 1) *conocimientos sobre el cambio climático y los fenómenos hidrometeorológicos*; sobre esta dimensión se obtuvo que 26.67% de los 105 estudiantes encuestados, consideraron que sus conocimientos sobre el tema son excelentes, mientras que para un 20.95% son buenos, un 18.10% considero sus conocimientos regulares, el 19.05% los consideró deficientes y finalmente un 15.24% consideró sus conocimientos sobre los fenómenos hidrometeorológicos como muy deficientes. En cuanto a la dimensión 2) *actitud*

y educación ambiental, ante el cambio climático y los fenómenos hidrometeorológicos. De 105 estudiantes que intervinieron en esta investigación, el 40% consideró que tienen una excelente actitud y educación ambiental, mientras que el 21.90% se valoró con una buena actitud. Dentro de las escalas regular un 18.10%, un 12.38% deficientes, y un 7.62% con una actitud y educación ambiental muy deficiente. Se concluyó que los conocimientos adquiridos sobre el cambio climático y los fenómenos hidrometeorológicos, se localizaron dentro de las escalas regular y baja, mientras que en la dimensión actitud y educación ambiental ante el cambio climático, se observó dentro de una escala buena; con base en el análisis expuesto se determinó que independientemente del bajo conocimiento que los estudiantes poseen sobre está dimensión, el 60% tiene una buena actitud y educación ante el cambio climático y los fenómenos hidrometeorológicos.

Palabras Clave: educación ambiental, huracanes, peligros, socioambientales, variabilidad climática.

Abstract

Education on biodiversity and climate change represents a significant pedagogical challenge. This study aimed to assess the knowledge, attitudes, and learning outcomes of students from the Colegio de Educación Profesional Técnica, Acapulco campus I, regarding biodiversity and its influence on climate change, as well as the associated risks and vulnerabilities stemming from hydrometeorological phenomena. The research employed a quantitative approach, with a descriptive scope and a cross-sectional design. The analysis focused on two key dimensions: 1) Knowledge of climate change and hydrometeorological phenomena. Among the 105 students surveyed, 26.67% rated their knowledge of the topic as excellent, 20.95% as good, 18.10% as fair, 19.05% as poor, and 15.24% as very poor. 2) Attitudes and environmental education related to climate change and hydrometeorological phenomena. Of the participants, 40% reported having an excellent attitude and level of environmental education, 21.90% rated theirs as good, 18.10% as fair, 12.38% as poor, and 7.62% as very poor. The findings indicate that students' knowledge of climate change and hydrometeorological phenomena predominantly falls within the fair and poor categories. In contrast, their attitudes and environmental education were generally rated as good. Therefore, despite limited conceptual understanding, 60% of students demonstrated a positive

disposition and educational engagement regarding climate change and hydrometeorological risks.

Keywords: environmental education, hurricanes, hazards, socio-environmental, climate variability.

Resumo

A educação sobre biodiversidade e mudanças climáticas é um grande desafio educacional. O objetivo desta pesquisa foi determinar os conhecimentos, atitudes e aprendizagens de estudantes do Colégio de Educação Profissional Técnica, plantel Acapulco I, sobre a biodiversidade e sua influência na mudança climática, bem como os riscos e vulnerabilidades por fenômenos hidrometeorológicos. O estudo tem uma abordagem quantitativa com alcance descritivo, de tipo transversal. A análise foi feita em torno de duas dimensões: 1) conhecimentos sobre as mudanças climáticas e os fenômenos hidrometeorológicos; sobre esta dimensão se obteve que 26,67% dos 105 estudantes entrevistados, consideraram que seus conhecimentos sobre o tema são excelentes, enquanto para 20,95% são bons, 18,10% consideram seus conhecimentos regulares, 19,05% os consideram deficientes e finalmente 15,24% consideram seus conhecimentos sobre fenômenos hidrometeorológicos como muito deficientes. Quanto à dimensão 2) atitude e educação ambiental, diante da mudança climática e dos fenômenos hidrometeorológicos. De 105 estudantes que intervieram nesta pesquisa, 40% consideraram ter uma excelente atitude e educação ambiental, enquanto 21,90% foram avaliados com uma boa atitude. Dentro das escalas regulares 18,10%, 12,38% deficientes, e 7,62% com uma atitude e educação ambiental muito deficiente. Concluiu-se que o conhecimento adquirido sobre a mudança climática e os fenômenos hidrometeorológicos, localizaram-se dentro das escalas regular e baixa, enquanto na dimensão atitude e educação ambiental diante da mudança climática, foi observado dentro de uma escala boa; Com base na análise acima foi determinado que, independentemente do baixo conhecimento que os alunos possuem sobre esta dimensão, 60% tem uma boa atitude e educação em relação à mudança climática e fenômenos hidrometeorológicos.

Palavras-chave: educação ambiental, furacões, perigos, socioambiental, variabilidade climática.

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Introduction

The recent and devastating hurricanes Otis – October 2023 – and John – September 2024 – struck the state of Guerrero, Mexico, where the city of Acapulco, one of the most important cities in the tourist field, was severely affected in its physical, social and environmental structures, directing global interest once again towards this emblematic city.

Thus, based on the aforementioned hydrometeorological phenomena, a reflective analysis of the knowledge that the general population, particularly the student sector, has about these increasingly frequent phenomena in this important tourist city is pertinent.

This approach addresses the knowledge that students have from the teaching-learning on biodiversity and climate change, topics covered within the *Biodiversity Identification study program* .

Within the literature analyzed, two main approaches to studying biodiversity stand out: the natural approach and the evolutionary dynamics approach. The natural approach defines biodiversity as biophysical-chemical processes and also includes the diversity of living beings (Audrin, 2022).

In the educational context, biodiversity can be addressed by teachers in biological sciences, geography, economics and even by history teachers, among other subjects (Gayford, 2000); which suggests an approach from different dimensions (Kassas, 2002), which allows students to link knowledge about biodiversity with environmental education and care for the environment (Audrin, 2022).

On the other hand, environmental vulnerability is understood as the outcome of the dynamics of a social group within its socio-environmental context. A society or social group may be considered vulnerable depending on its capacity to resist, survive, and recover from the impacts of ~~a~~ natural hazards, such as hydrometeorological phenomena (Shah *et al*., 2020).

Shah *et al*. (2020) refer to the various vulnerabilities to which societies or communities may be exposed, stemming from the relationship between society and nature. This translates into a close socio-environmental relationship arising from natural phenomena, such as storms and hurricanes, as well as the use of natural resources.

In this sense, the misuse and overexploitation of natural resources has generated an environmental crisis of alarming proportions. Leff (2004) asserts that this crisis is rooted in human symbolic nature, as it is not only a mutation from modernity to postmodernity, but also encompasses an epistemic shift, an ecological change, and a process of deconstruction.

Evidence shows that humanity is facing an acute climate crisis. The deterioration is ongoing; pollution spreads through the soil, water, and air, with an enormous impact that overwhelms ecosystems. The sea level and ocean temperatures have risen at an alarming rate.

Intense droughts, constant fires, floods, water scarcity, catastrophic storms and polar ice melt have all contributed to the decline in biodiversity; these imbalances in ecosystems are the perfect ingredients for climate change (United Nations [UN], n.d.).

Hauberg-Lund (2019), Crutzen and Stoermer (2021), Calixto-Flores (2022) and Valladares Riveroll (2022) have documented that climate change has a natural origin because it is caused by natural factors such as volcanic eruptions, hurricanes, extreme droughts or the burning of biomass, among other events.

Conversely, climate change is anthropogenic, resulting from human productive activities. These activities typically involve the intensive exploitation of natural resources with no compensation for the services provided by nature, which are ultimately converted into greenhouse gases that contribute to climate change (Henderson et al., 2017; Calixto-Flores, 2022).

The current chaotic socio-ecological relationship has reached alarming levels, leading to negative transformations in ecosystems. Therefore, it is recommended to create spaces for debate and discussion that enable the problem to be addressed from multiple academic disciplines, as proposed by Wolfesberger *et al*. (2024).

In this regard, Crutzen and Stoermer (2021) assert that humanity will be considered a predominant environmental force for thousands of years due to its active participation in natural areas such as geology, biology, or ecology, and the anthropogenic effects on the biosphere and ecosystems.

Given this scenario of climate crisis, studies on biodiversity and climate change are relevant, as pedagogical practices, to understand the risks and vulnerabilities to which one is exposed by natural phenomena, as well as the socio-environmental consequences.

Background

It is important to remember that the environmental crisis is not a recent problem; since the 1940s, scientists and environmental scholars have warned about the damage sustained by ecosystems and the negative anthropogenic impacts that have contributed to their degradation.

Leopold (2019) highlights the importance of treating nature ethically and proposes further studies on conservation and ecological awareness emphasizing that humans should be regarded as part of nature rather than treating nature as property.

He insisted that there should be an ethical relationship between contemporary society and nature. In his work “A Sand County Almanac”, Leopold recommends that before carrying out human activities, the use of land, water, flora and fauna, as a whole, should be considered in all ecosystems (Leopold, 2019).

In this respect, Carson (2002) warned about the great environmental disaster caused by the chemical and agrochemical industries and the massive effects of pesticides on the population and nature, reiterating the negative effects on the health of ecosystems and the human species.

Thus, “A Sand County Almanac” by Leopold (2019) and “Silent Carson's spring" (2002) were considered the first environmental movements in favor of the protection and conservation of nature; these investigations warned about the damage being caused to ecosystems at a planetary level.

In this sense, Hauberg-Lund (2019) and Crutzen and Stoermer (2021) argue that humanity plays a central role in industrial, economic, and consumer activities, which have produced devastating impacts on ecosystems, led to the emergence of the Anthropocene epoch.

Hence, the Anthropocene period is attributed precisely to the industrial revolution (Trischler, 2017), from the 18th century onwards there began an accelerated growth in all economic sectors, especially in the industrial sector, which resulted in the overexploitation of natural resources; this stage is known as the “age of human beings” (Crutzen and Stoermer, 2021).

Valladares Riveroll (2022) asserts that the Anthropocene highlights the intersubjective and interobjective relationship with the environment, demonstrating the profound dependence of human beings on natural resources. Consequently, humanity is depleting natural resources, exhausting them, and thereby endangering its own survival.

In this regard, Hauberg-Lund (2019) asserts that the exponential consumption of natural resources and accelerated overexploitation have led to the degradation of the biosphere, rising temperatures of the Earth and its oceans, and consequently, the occurrence of climatic events such as increasingly powerful storms and hurricanes that pose serious risks to human populations.

Undoubtedly, a socio-ecosystemic relationship exists given the profound dependence of human beings on ecosystems for their survival. (Audefroy and Padilla-Lozoya, 2018; Bengtsson, 2019) assert that this deep relationship of codependency has increased environmental degradation and, consequently, the risks and threats to the population from natural phenomena are more frequent and intense.

While Pietrocola *et al*. (2021) and Valladares Riveroll (2022) state that these events are produced and often caused by human actions and decisions, specifically those driven by the prevailing economic model, as well as by human interventions in wildlife and, more broadly, in ecosystems.

Natural phenomena are closely related to human activities; productive and economic activities, where natural resources are overexploited or, failing that, are contaminated by being used in an unbalanced way, thus violating and altering ecosystems, which ultimately translates into highly devastating natural phenomena that put human beings at risk (Gervacio Jiménez *et al.*, 2024).

For their part, Audefroy and Padilla-Lozoya (2018) assert that ongoing deforestation, resources overexploitation, wildlife trade are anthropogenic activities that have contributed to the ecosystem deterioration.

The analysis of these background factors reveals that humanity faces an uncertain and concerning scenario. The planet shows clear signs of distress and requires concrete actions to support ecosystems, in order to enable their restoration and recovery.

In this case, it is necessary to address the environmental problem from formal education, starting from eco-education; from educational pedagogical practices, so that the curriculum emphasizes and insists on addressing topics that involve the environmental aspect in an integrated way.

Environmental education has long been been discussed as a strategy to combat pollution and mitigate climate change. Alzate (2013) acknowledges that, within a context of environmental uncertainty, diverse pedagogical approaches have been developed to address the socio-environmental complexities and vulnerabilities faced by population.

Hauberg-Lund (2019) argues that the planetary crisis requires a pedagogy of vulnerability and risk, in which humanity transcends anthropocentric views and develops socio-ecological processes grounded in the responsibility of recognizing itself as an intrinsically vulnerable being and co-constituted with the environment.

Environmental pedagogy dates back to various international academic events, such

as the Stockholm Conference (1972), International Environmental Education Programs (1975-1981), the Tbilisi Conference (1977), among others.

These meetings addressed the importance of promoting environmental education in the formal and non-formal curriculum, and that its approach be transversal, considering both the natural and social aspects (Gervacio Jiménez and Castillo Elías, 2019).

It has been proven that the study of nature and its close relationship with human beings has been approached from different approaches and perspectives, with the aim of fostering effective educational processes. In this context, intuitive pedagogy emerged, characterized by concrete observation, socioeconomic motivation to value productive practices, and the use of morality to strengthen student within their environment (Giolitto, 1984).

The aim of environmental pedagogies is to promote attitudes that foster understanding of how the environment functions, through positive attitudes (Valero Avendaño and Castellanos Gómez, 2017), so that students develop the awareness and knowledge necessary to contribute to the care of nature.

Educational proposals to curb climate change are already being implemented by the United Nations (UN). In addition to promoting the reduction of greenhouse gas emissions, more effective governmental education policies have been designed to address climate change, with the aim of raising awareness and educating a broader public (Iberdrola, 2025).

Since 2012, other initiatives promoted by the United Nations, such as the Sustainable Development Goals, have been developed with the aim of combating the impacts of climate change (UN, 2013).

These objectives have been incorporated into institutional educational plans in Mexico and implemented in the school curriculum of basic education in the current Mexican School Program.

However, the knowledge acquired in the classroom must be tested and applied in response to the climate challenges humanity is currently facing. Especially at the local level, coastal areas, such as the city of Acapulco in the state of Guerrero, have experienced intense hydrometeorological events, including the recent hurricanes Otis and John.

The impacts and devastation of these two natural phenomena have put the population in a precarious situation and national and local authorities on high alert. Therefore, addressing these issues in schools is crucial for every student in this affected community.

Problem statement:

The various climatic events that have altered biodiversity in ecosystems, along with the socio-environmental problems observed, as well as the constant, rapid environmental deterioration, demand immediate attention.

The different environmental problems must be addressed and studied from different contexts, dimensions, and approaches; one of these is the socio-environmental dimension, beginning with formal education, anchored in the educational curricula that promote knowledge and strategies to generate actions that contribute to the care of nature.

Similarly, non-formal environmental education is important and necessary to consolidate knowledge and practice on issues related to the social and natural environment.

This research emerges from the environmental contingency caused by the two hydrometeorological phenomena: Hurricane Otis in 2023 and Hurricane John in 2024. These events triggered a climatic, social, and economic crisis that affected the population of the state of Guerrero, directly impacting the students under study.

The relevance of this research lies in the opportunity provided by the Classroom, School, and Community Program (PAEC), which enables upper secondary education students to construct contextualized learning through the study and analysis of the problems in their community. Within this framework, students can develop Community School Projects (PEC) (Secretariat of Public Education [SEP], 2023).

Through the PEC students experience, reflect and discover that knowledge becomes useful and meaningful when applied in daily life. Through their direct participation, they have the opportunity to propose alternative solutions to community problems of a social, environmental, cultural or economic nature, applying *in situ* what they have learned in the classroom (SEP, 2023).

In this sense, it is relevant to analyze and reflect on the knowledge and environmental attitude that students demonstrate in the face of the current climate emergency and the vulnerability to which they are exposed by hydrometeorological phenomena, as evidenced by hurricanes Otis and John, where the students under study were immersed and in constantly at risk.

Research question:

To what extent are the students under study able to apply their knowledge, skills, and competencies to natural phenomena such as hurricanes in order to safeguard their physical integrity?

Aim

To determine the knowledge, attitudes and learning outcomes of students at the College of Professional Technical Education, campus I Acapulco, regarding biodiversity, climate change, risks and vulnerabilities associated with hydrometeorological phenomena and socio-environmental impacts.

Methodology

This research was conducted in the context of two hydrometeorological phenomena, Hurricane Otis in October 2023 and Hurricane John in September 2024, the latter having a major impact on the city and port of Acapulco as well as on the state of Guerrero.

In this sense, it was considered pertinent to conduct the present investigation, given the extent of the effects that Hurricane John had on the population under study.

The student sample belongs to the College of Professional Technical Education (CONALEP), Acapulco campus I, located in Las Cruces, Acapulco, Guerrero, Mexico.

The study has a descriptive scope and cross-sectional design as it evaluates the level of knowledge, learning, and attitudes acquired by the students; it is cross-sectional because the research was carried out at a specific point in time (Hernández-Sampieri and Mendoza, 2018).

The participants in this study are fifth-semester students who completed the module *Identification of Biodiversity*, which addresses cyclonic events and topics related to climate change, among other socio-environmental aspects that are part of the institutional curriculum.

The data was collected through an invitation to students who had already completed the module.

The research adopts a quantitative approach (Hernández-Sampieri and Mendoza, 2018), employing a survey administered through Google Forms. A purposive and convenience sampling technique was applied (Chacón *et al*., 2022).

Accessibility to the sample was taken into account, as the participating students had directly experienced the impacts of the two hydrometeorological phenomena; their contribution is therefore considered significant for the present study (Varguillas, 2006).

The survey was conducted from October 8 to October 18, 2024, during the first two weeks after students returned to the classrooms following Hurricane John.

The main reason for administering the survey immediately upon their return to the classroom was to capture students' descriptions of their recent experiences with the unexpected natural phenomenon.

The survey consisted of two sections of 10 questions each, using a Likert scale. The first section focused on the dimension of *knowledge about hydrometeorological phenomena and knowing how to act in the face of these natural phenomena.*

The second block considered the dimension: *attitude and environmental education*, focusing on the ways in which students respond to hydrometeorological phenomena that have caused devastation at both national and global levels.

The population size consisted of 128 students, based on the finite sample size calculation, a final sample of 105 was obtained, with a confidence level of 95%, and a maximum accepted margin of error of 5%.

$$n = \frac{N * Z^2 * p * q}{E^2 * (N-1) + Z^2 * p * q}$$

n: Sample size (n=105)

N: Size of the population or universe (N=128)

Z: Statistical parameter that depends on the confidence level (Z=1.96)

E: Acceptable margin of error (E=0.05)

p: Probability of the studied event occurring (p=0.5)

q: Complementary proportion (q=0.5)

The process of conducting the survey was driven by the events prior to Hurricane John. Students returned to the classroom two weeks after the cyclonic event; therefore, it was considered appropriate to document the experiences and strategies that the students implemented.

The questionnaire was designed with questions aligned to the research question. Closed-ended questions were chosen to minimize omissions; in this case, a five-point ordinal scale was employed: excellent, good, fair, poor, and very poor (Grasso, 2016).

The survey was administered through Google Forms. A total of 105 responses were collected. The resulting database was subsequently processed using IBM SPSS Statistics v.22 software for statistical data analysis (Hernández-Sampieri and Mendoza, 2018; Varguillas, 2006).

Variables were grouped to capture the overall perception of students' level of knowledge on five specific topics, within the two dimensions previously mentioned:

1.-Knowledge about hydrometeorological phenomena and their socio-environmental impacts.

2. Knowledge about the dangers and vulnerabilities to which you are exposed by natural phenomena.

3. Knowledge about climate change and global warming.

4.- Perception of the complexity of environmental problems in the local environment.

5.-. Attitude and practices with the local environment.

The results obtained from the two dimensions are presented below:

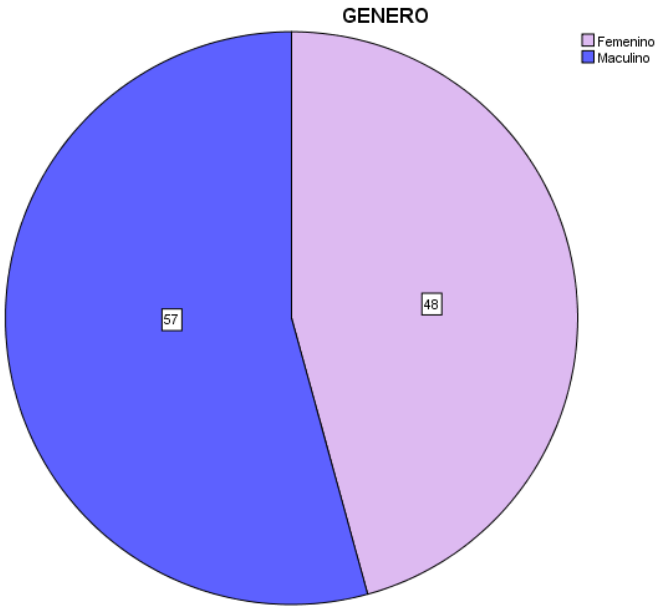
1) *Knowledge about climate change and hydrometeorological phenomena.*

2) *Attitude and environmental education towards climate change and hydrometeorological phenomena.*

Results

Initially, the instrument was piloted with 30 students from the same semester who were not part of the sample but had previously taken the module of Biodiversity Identification. The instrument showed high internal consistency according to Cronbach's alpha ($\alpha = 0.99$), suggesting that the responses were consistent across participants. The participants in this study consisted of 57 male and 48 female students (Figure 1).

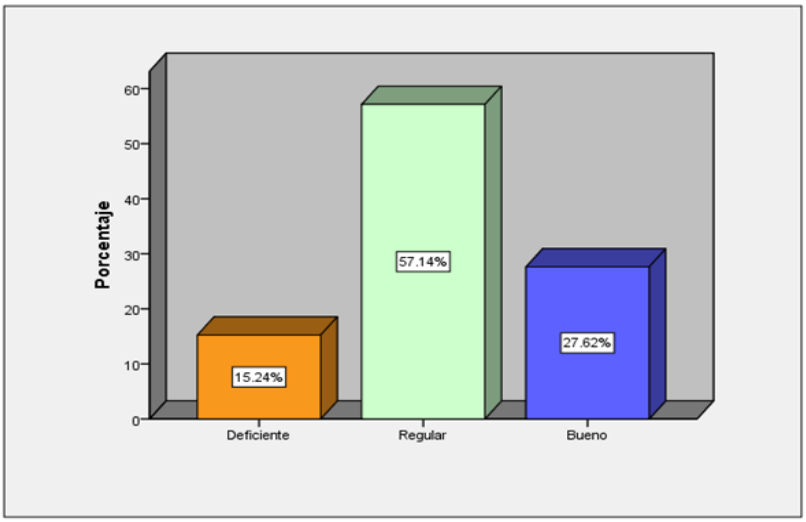
Figure 1. Gender breakdown of surveyed students



Source: Own elaboration

Since knowledge is fundamental for students to develop awareness and form their own opinions, the responses corresponding to the knowledge dimension are presented below. It was observed that, when asked about the *level of knowledge acquired regarding hydrometeorological phenomena and their socio-environmental impacts*, 57.14% considered their knowledge to be at a fair level, while 27.62% rated their knowledge as good, and 15.24% considered their knowledge to be deficient (Figure 2).

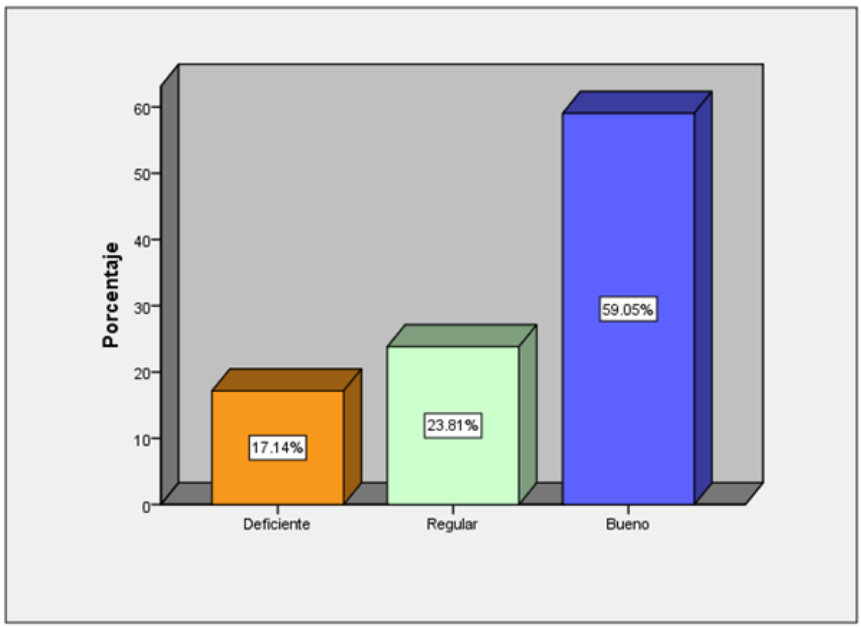
Figure 2. Knowledge about hydrometeorological phenomena and their impacts



Source: Own elaboration

It is essential that students understand the magnitude of the danger to which they are exposed and recognize their degree of vulnerability. In this regard, 59.05% considered themselves to have good knowledge *about the dangers and vulnerabilities to which they are exposed by natural phenomena*, while 23.81% rated their knowledge of the dangers and vulnerabilities as fair and 17% as deficient (Figure 3).

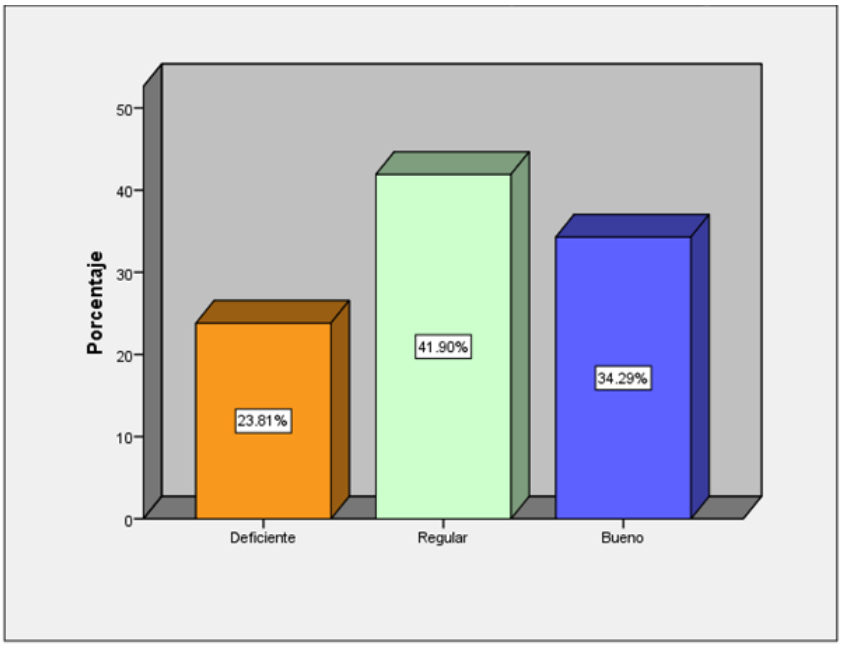
Figure 3. Knowledge about the hazards and vulnerabilities to which one is exposed by natural phenomena.



Source: Own elaboration

Regarding the variable *of knowledge about climate change and global warming*, 41.90% considered their knowledge to be average, while 34.29% considered their knowledge to be good, and 23.81% of the students surveyed considered their knowledge to be deficient on this topic (Figure 4).

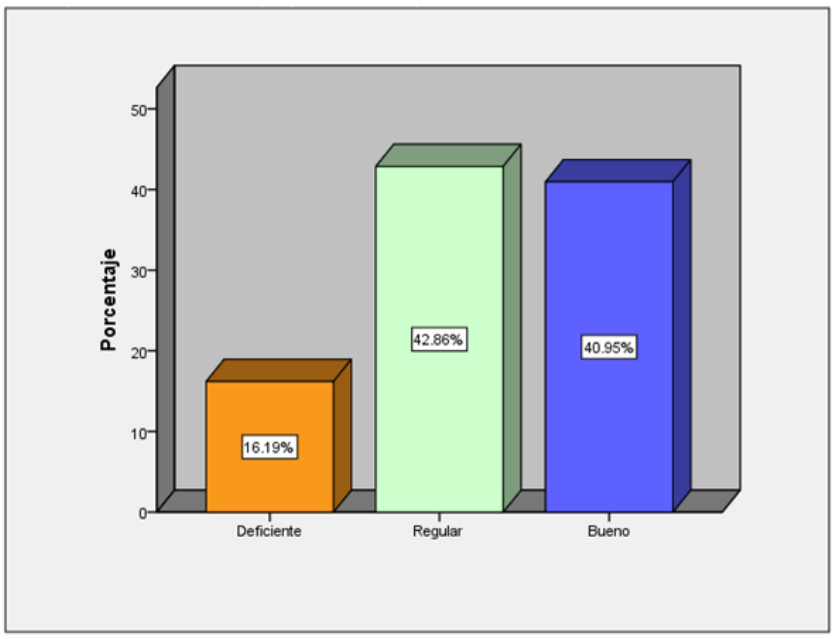
Figure 4. Knowledge about climate change and global warming.



Source: Own elaboration

Regarding the question of how students perceive environmental problems, 42.86% considered their perceptions of the complexity of environmental problems in the local environment to be average, while 40.95% rated it as good and 16.19% as poor (Figure 5).

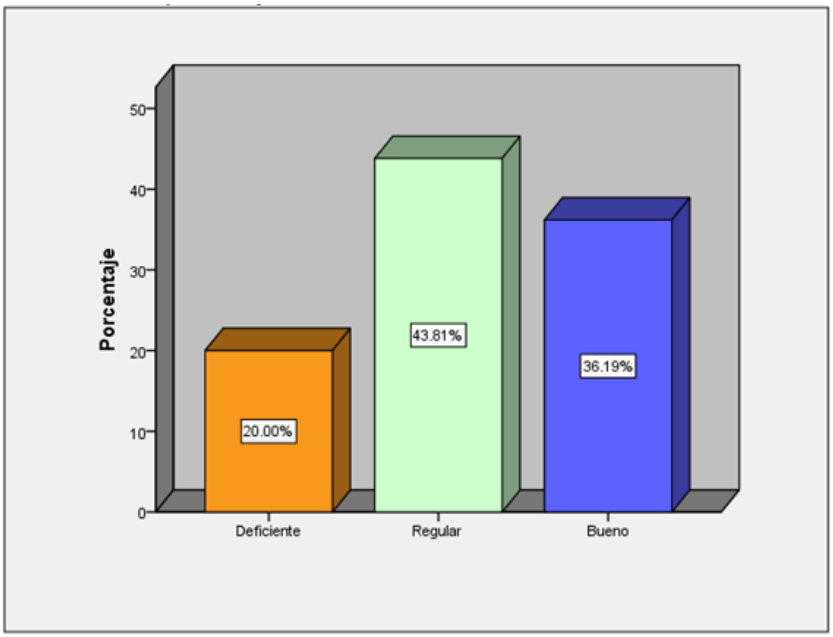
Figure 5. Perception of the complexity of environmental problems in the local environment



Source: Own elaboration

Regarding the question about attitude and practice with the local environment, 43.81% considered themselves to have a regular commitment, while 36.19% considered their practice and attitude to be good, and finally 20% of the students considered themselves to have a deficient practice and care with the local environment (Figure 6).

Figure 6. Attitude and practice with the local environment



Source: Own elaboration

Once the previous results were analyzed, the results of the two grouped dimensions are presented below: 1) *knowledge about climate change and hydrometeorological phenomena and 2) attitude and environmental education, regarding climate change and its relationship with hydrometeorological phenomena.*

Based on the analysis of the results on the dimension *"Knowledge about hydrometeorological phenomena"*, which includes a block of 10 questions, as shown in figure 7, 26.67% of the 105 students surveyed, rated their knowledge of the subject as excellent, while 20.95% rated their knowledge of hydrometeorological phenomena as good.

In this regard, as shown in the results, only 47.62% of the students considered their knowledge of hydrometeorological phenomena to be between excellent and good.

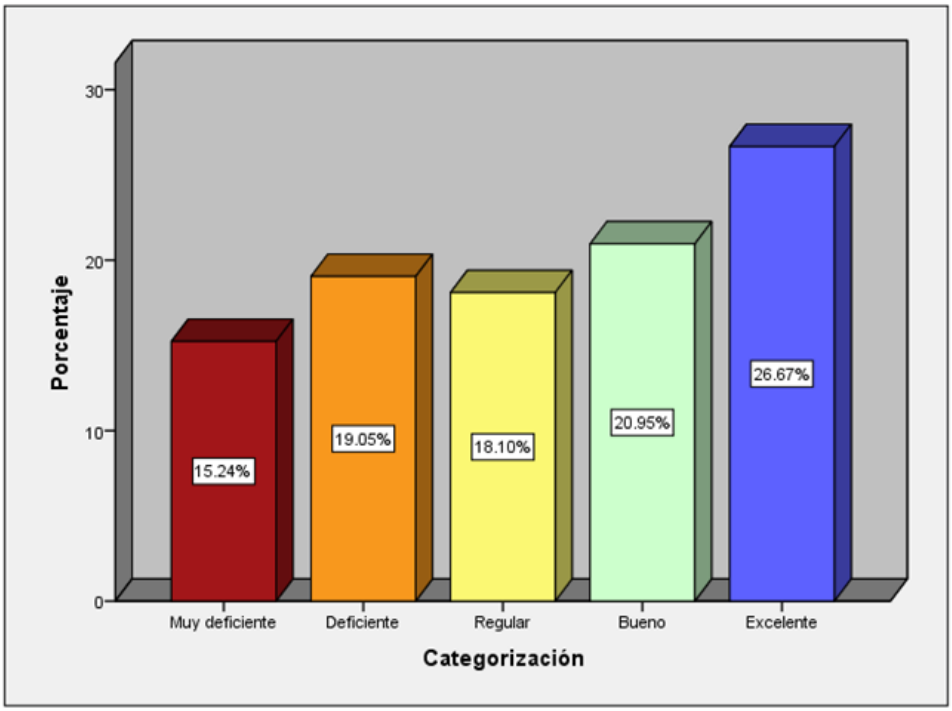
While 18.10% rated their knowledge as fair, 19.05% considered it deficient, and finally, 15.24% considered their knowledge of hydrometeorological phenomena to be very deficient.

The results presented showed that knowledge about hydrometeorological phenomena tends towards a regular level of knowledge (52.38%).

Based on the results obtained here, the positive percentages between the excellent scale and the good scale add up to 47.63%, which indicates that the students' knowledge is observed to be below 50%.

In this regard, it was determined that 52% of students do not have the knowledge to deal with the hydrometeorological phenomena of their local environment. (Figure 7).

Figure 7. Percentage on the dimension of knowledge about climate change and hydrometeorological phenomena



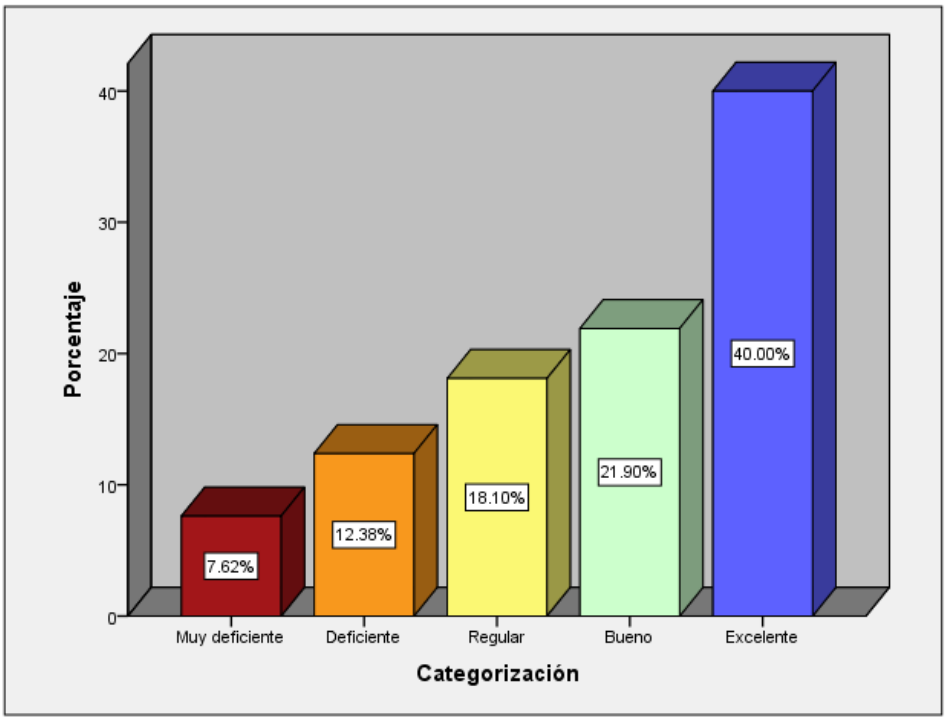
Source: Own elaboration

Regarding the dimension, *attitude, and environmental education that students possess towards hydrometeorological phenomena*, it can be observed that of the 105 students who participated in this research, 40% considered that they have an excellent environmental attitude, 21.90% their attitude is good, while 18.10% observed a regular attitude, while 12.38% considered it deficient and 7.62% very deficient.

Therefore, it was determined that 62% of the students under study have a positive attitude and environmental education towards climatic phenomena such as hurricanes, while

38% have a regular to deficient attitude, so it can be determined that the students have a good attitude regardless of their knowledge about climatic phenomena (Figure 8).

Figure 8. Attitude and environmental education towards climate change and its relationship with hydrometeorological phenomena



Source: Own elaboration

A comparative analysis was carried out on both dimensions: 1) *knowledge about climate change and hydrometeorological phenomena* and 2) *attitude and environmental education that students possess towards hydrometeorological phenomena*, the results showed that the knowledge that students possess has a tendency below 50%.

While in *the dimension of attitude and environmental education*, the trend was above 60% of students who considered themselves to have a good attitude towards climate events.

Discussion

This study addressed the knowledge and attitudes that students have after completing the *Biodiversity Identification module* with socio-environmental content related to climate change, resilience, and vulnerability, within the framework of the recent hydrometeorological phenomena in which the students of this study were immersed.

The results obtained in this research show that even though students have studied the problems addressed in this research, and which are included in the curriculum, it does not mean that they have assimilated significant knowledge to make preventive decisions in the face of a large-scale phenomenon such as hurricanes.

Given the findings obtained, other research related to the topics addressed in this investigation was reviewed and analyzed, with results similar or adverse to this study, which provide clarity on the problem addressed.

The results obtained by Gervacio and Castillo (2019, 2020), on the environmentalization in the curriculum and the knowledge, attitudes, and socio-environmental practices of high school students, coincide precisely with the results obtained in the present research, since it was observed that the environmental knowledge and training acquired ranges from "regular" to "scarce", the results are similar to those obtained in this study.

Within the same investigation, students were asked if they know how to act in the face of socio-environmental problems that arise in daily life in their local environment; the students' responses were established within a regular scale (Gervacio and Castillo, 2020).

In contrast to the results obtained in this research, the students opined that regardless of their knowledge, 60% expressed knowing how to act in the face of environmental problems.

Thus, other investigations such as that of González and Meira (2020), which addressed education in the context of climate change, verified that the results revealed several aspects, among which it is emphasized that knowledge becomes meaningful only when students engage in real activities that impact their community.

This suggests that, as long as curricular content is only learned in theory and remains confined to the classroom, it will constitute knowledge without practical use.

In this study, González and Meira (2020) recommend revisiting the students' previous experiences so that they acquire meaningful learning through their encounters with disasters, enabling them to reflect on those experiences by connecting the abstraction of climate change with everyday life.

When comparing this research, it was observed that only 26% considered that they had excellent knowledge, the rest were between the good, regular, and poor scales.

In this regard Muttarak and Lutz (2014) stated that the knowledge acquired on issues of biodiversity and climate change allows the population to reflect more clearly on local

emergency situations, as well as the daily needs of the community, adopting a different attitude to make informed decisions with clear options on the action strategies to follow.

In light of the cited research and in relation to the results of this investigation, regarding students' perception of the complexity of environmental problems in their immediate environment, it was found that they considered themselves to have a good understanding of the complexity of environmental problems.

This suggests that students do perceive environmental threats and problems, as mentioned by González and Meira (2021), that students must live their own experiences to acquire knowledge and awareness.

In this sense, this research indicates that the experiences lived during hurricanes Otis and John left students with more knowledge than what is learned in school classrooms.

Studies such as Gayford (2000) determined that there could be other factors that prevent students from achieving positive results.

Their study analyzed teachers' attitudes and approaches to biodiversity and climate change education in the United Kingdom.

The research found that, while the programs included many essential components of knowledge for education on biodiversity and climate change, little was generally done to ensure that students achieved a more coherent understanding of complex issues such as climate change, risks, or vulnerabilities, considered controversial topics to address.

These results suggest that teachers can have a positive or negative impact on learning outcomes, as demonstrated by Gayford (2000).

In his research Gayford (2000) states that the study of biodiversity and climate change can be approached by teachers trained in different areas, ranging from biological sciences, geography, economics and even history teachers; these profiles allow an approach from different dimensions.

Kassas (2002) confirms this position when he suggests that the integration of different disciplines favors the development of knowledge.

Similarly, Audrin (2022) argues that addressing biodiversity through different approaches enables it to be understood in different ways, depending on the professional profile being addressed.

Audrin (2022) evaluated how biodiversity is understood and presented as part of environmental education in the compulsory education curriculum in French-speaking Switzerland.

The data obtained confirmed that biodiversity is a central element of the program, which fosters a scientific approach emphasizing the importance of interdisciplinarity in environmental studies (Audrin, 2022).

Audrin's research (2022) showed that the programs broadly address the impact of human behavior, delving into the consumption of natural resources and energy.

This analysis shows that curricular programs should adopt a holistic view of the concept of life, integrating scientific and environmental aspects, such as the case of biodiversity education and climate change.

In this regard, Valladares Riveroll (2022) analyzed the incorporation of disaster education into the Mexican education system. Her results revealed that the approach is psychological, individualistic, and non-participatory, and is limited to formal education, lacking clear connections with extracurricular activities. These findings could explain the limited knowledge and moderate attitudes of the students in this study.

In this same context, it was examined the analysis carried out by González Gaudiano and Meira Cartea (2020) on the role of social sciences, education, and the study of climate change; their results demonstrated that there is an apparent apathy from the two aspects they analyzed, they determined that educating for climate change is not only a necessity, but is considered an urgency, and must be clearly declared as an emergency from the school curriculum and addressed from different disciplines.

In this sense, González Gaudiano and Meira Cartea (2020) consider that action must be taken in the face of climate change and treat it as an emergency to avoid catastrophic scenarios due to climate collapse. They recommend a climate emergency curriculum that accompanies, socializes, and reinforces climate policies for adaptation and mitigation, in response to the runaway scenarios generated by natural phenomena, such as Hurricane Otis and John.

On the other hand, a study by Kassas (2002) highlights that biodiversity education is often part of environmental education and aims to develop awareness and concern of the entire population towards and for the environment.

The results of this research reveal that, in light of the two recent hydrometeorological phenomena, students do not always have a good level of knowledge about these climatic emergencies and their consequences; however, it is possible that experience enable them to act positively, so that they make use of common sense and apply the knowledge acquired only for prevention.

The results of this research largely coincide with the results of Gayford (2000), González Gaudiano and Meira Cartea (2020) and Valladares Riveroll (2022), who, as in this study, did not report positive outcomes in their investigations.

Given this scenario, it is important to emphasize the need to continue documenting the findings, experiences, and efforts that have been carried out in other universities and in the different educational subsystems that have promoted programs on the study of biodiversity and climate change.

In this context, and given the climate crisis caused by human activities, there is an urgent need to educate the population to prepare them for natural phenomena that ultimately translate into socio-environmental disasters, such as hurricanes or earthquakes. In this regard, Shaw *et al*. (2011), Preston (2012), and Dufty (2020) emphasize the urgency of creating educational spaces that directly address and deal with disaster education.

Research such as "education in case of disasters", "education about disasters", "education on disaster risk", "pedagogy of disaster prevention", "education for resilience", "education in emergencies", among others (Kitagawa, 2017), "education for disaster risk reduction as a practice of public pedagogy (Valladares Riveroll, 2022), to mention some research works that address climate crises.

The previous references conclude that knowledge alone is insufficient; action must be taken, as environmental emergencies are becoming increasingly frequent and bring significant impacts that affect the population.

From the perspective of Petrie *et al*. (2020), it is necessary to learn and develop new educational practices, based on innovative languages, transformative pedagogies that modify intersubjective and interobjective relationships, of respect and solidarity for the environment.

The results obtained by Valladares Riveroll (2022) show that the Mexican School curriculum has areas of opportunity that must be addressed mainly in the prevention of disasters caused by anthropogenic impacts and of course, natural events.

Similarly, Biesta (2012), Ojala (2012) and Kitagawa (2017) report on the importance of education in the face of threats and catastrophes that grow and diversify throughout the world as part of everyday life (Lorenzo *et al.*, 2019).

Valladares Riveroll (2022) suggests that students must develop the ability to recover environmental awareness and to revitalize and transform public life from socially desirable, fair, and safe contexts.

Conclusions

This research highlighted the importance of formal education in acquiring knowledge and positive attitudes towards environmental problems and how biodiversity is perceived in the face of climate change.

In this sense, the path to understanding and preserving biodiversity and addressing the problems generated by climate change is undoubtedly through formal education.

A curriculum that integrates innovative pedagogies for the study of biodiversity and climate change can enhance students' learning and strengthen their capacity to prevent and respond to natural events.

The new Mexican School has launched educational initiatives that contribute to addressing climate change by promoting the conservation of electricity and water through key themes such as socio-environmental responsibility.

Similarly, the active participation of students is prioritized to adapt to climate change and thus reduce the possible impacts of climate change.

Consequently, the study and teaching of biodiversity and climate change are incorporated into educational institutions enabling students to develop good habits for caring and protecting the environment and maintaining ecosystem health.

These initiatives aim to promote the study of the climate crisis in schools through projects focused on natural events such as Hurricanes Otis and John, helping students understand that these phenomena are not isolated from everyday life.

The experience with the two hydrometeorological phenomena that interrupted the school activities of thousands of students in the study area has also promoted several prevention projects in educational centers.

In this sense, the school has an important role in the care and protection of students and the community in general since the facilities functioned as shelters and collection centers in the face of weather events.

Although the results did not reveal significant advances in knowledge about biodiversity and climate change, it is relevant to document the actions being undertaken in schools through educational programs.

Implementing changes to the curriculum and putting them into practice entails a long process for its application, as it is recommended that curricular initiatives be supported by the educational community and by social actors who actively participate.

Finally, this research provides data that allows us to understand how the sample of students from this subsystem perceive their knowledge and the attitude they have towards climate change and hydrometeorological phenomena.

The data obtained can serve as a basis for further exploration of environmental studies on curriculum development, socio-environmental management, and sustainable educational projects with the aim of having more informed and resilient schools, students, and communities in the face of potential climate events.

Future lines of research

This research will allow us to explore other lines of research on the topics covered in this study and related to the environment and curriculum environmentalization.

Based on the data obtained, further research could be generated from the curricular exploration of other subsystems at the basic level, allowing for a comparison and determination of approaches to biodiversity and climate change at the institutional level.

On the other hand, investigating the knowledge and attitudes that students from other subsystems have regarding the protection of ecosystems and climate events would be advisable to determine if they are prepared to act accordingly or if the knowledge only remains within the classroom.

Similarly, it is pertinent to open lines of inquiry into how teachers perceive environmental issues and challenges, their knowledge and participation, the curricular approaches adopted, as well as the methods they employ to integrate curricular content with environmental issues from the perspective of their professional profiles.

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