Development of an Educational Application for Recording Rainfall Data in Pinheiro, Maranhão, Brazil

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Abstract

Precipitation monitoring is fundamental for understanding climate variability, environmental planning, and water resource management, especially in regions with irregular rainfall regimes. This study aimed to develop and apply an educational application for recording, organizing, and analyzing pluviometric data in the municipality of Pinheiro, Maranhão, while promoting student engagement in scientific and technological practices. The Rain Observer application was developed using the Flutter framework and integrated with Google Forms and Excel Online, enabling automatic data storage and the creation of a continuous rainfall database. Daily precipitation measurements were conducted from January to August 2025 using a conventional 150 mm rain gauge installed at the Federal University of Maranhão, Campus Pinheiro, following GLOBE program protocols. The results indicate that the application improved data standardization, reliability, and recording efficiency, reducing errors associated with manual notes. The analysis revealed an average precipitation of 9.1 mm/day, with high temporal variability and rainfall events concentrated between January and April, typical of tropical climates. From an educational perspective, the project contributed to the development of scientific thinking, digital literacy, and environmental awareness, demonstrating the potential of educational applications for local climate data production and learning promotion in school environments.

Keywords: Application development, Mobile programming, GLOBE, STEAM.

Research Question and Hypothesis:

Research Problem

Based on this understanding, this study sought to investigate how the development and application of an educational mobile application can contribute to improving the recording, organization, and analysis of pluviometric data in the municipality of Pinheiro, Maranhão, while promoting the active participation of students from schools in various municipalities in the region in climate monitoring and strengthening scientific and technological literacy in the school context. Therefore, this study aims to address the following questions:

- How can an educational application improve the recording and organization of pluviometric data in Pinheiro, Maranhão?
- How does student participation in rainfall monitoring through the application contribute to scientific learning and educational engagement?

- In what ways does the use of digital tools strengthen students' scientific and technological literacy?
- How can educational applications be used as tools for climate monitoring and for promoting learning in the school environment?

Hypothesis

The use of an educational application for recording pluviometric data makes the process of data collection and storage more organized, efficient, and reliable, replacing the use of manual spreadsheets. In addition, it is assumed that this tool stimulates the engagement of elementary and high school students in climate monitoring and contributes to the development of scientific, digital, and environmental competencies in the school context in municipalities of the Baixada Maranhense and Maranhense Coastal Zone.

1. Introduction

Rainfall precipitation is one of the main elements for understanding climatic processes and for the sustainable management of water resources, being fundamental for territorial planning, agriculture, and the prevention of natural disasters. The absence or insufficiency of local rainfall records compromises the development of effective environmental policies and limits the analysis of regional climate patterns, as highlighted by Costa et al. (2020). In this context, systematic precipitation monitoring becomes essential, especially in regions with high climatic variability.

Advances in digital technologies have significantly contributed to the democratization of science and to the strengthening of collaborative practices in data production. Recent studies indicate that the use of mobile devices and educational applications enables citizens to actively participate in the collection, recording, and sharing of environmental information in near real time, expanding the spatial coverage of climate observations (Nunes & Bastos, 2023). This scenario favors the development of citizen science, in which the community acts as a protagonist in the production of scientific knowledge.

In the municipality of Pinheiro, Maranhão State, Brazil,, characterized by irregular rainfall regimes and the influence of regional atmospheric systems, the proposal for pluviometric

monitoring through an educational application presents high scientific and social relevance. The initiative contributes to the articulation between scientific knowledge, technology, and environmental responsibility, while stimulating youth protagonism and the consolidation of a culture of scientific investigation in the school environment.

Pedagogical methodologies based on solving real-world problems have demonstrated potential to promote more meaningful learning. As highlighted by Lacerda and Figueiredo (2022), the integration of technological projects in secondary education favors the development of intellectual autonomy, critical thinking, and collaborative work. In this sense, the replacement of manual records with digital data collection systems represents a growing trend, especially in educational projects, as it facilitates the organization of information and makes the research process more dynamic and accessible to students (Silva & Pacheco, 2021).

In addition to its educational character, the creation of a local-scale pluviometric database constitutes an important instrument to support both public management and scientific research, allowing the monitoring of climatic trends and supporting mitigation and adaptation strategies to environmental impacts (Borges et al., 2023). Thus, the results of initiatives of this nature go beyond the school environment and generate concrete contributions to the community.

Finally, the proposal is aligned with the guidelines of the National Common Curricular Base (BNCC), which emphasizes the use of investigative methodologies and the development of digital, scientific, and socio-environmental competencies in the teaching–learning process (Brazil, 2022), reinforcing the educational and social relevance of the research.

2. Methods and materials

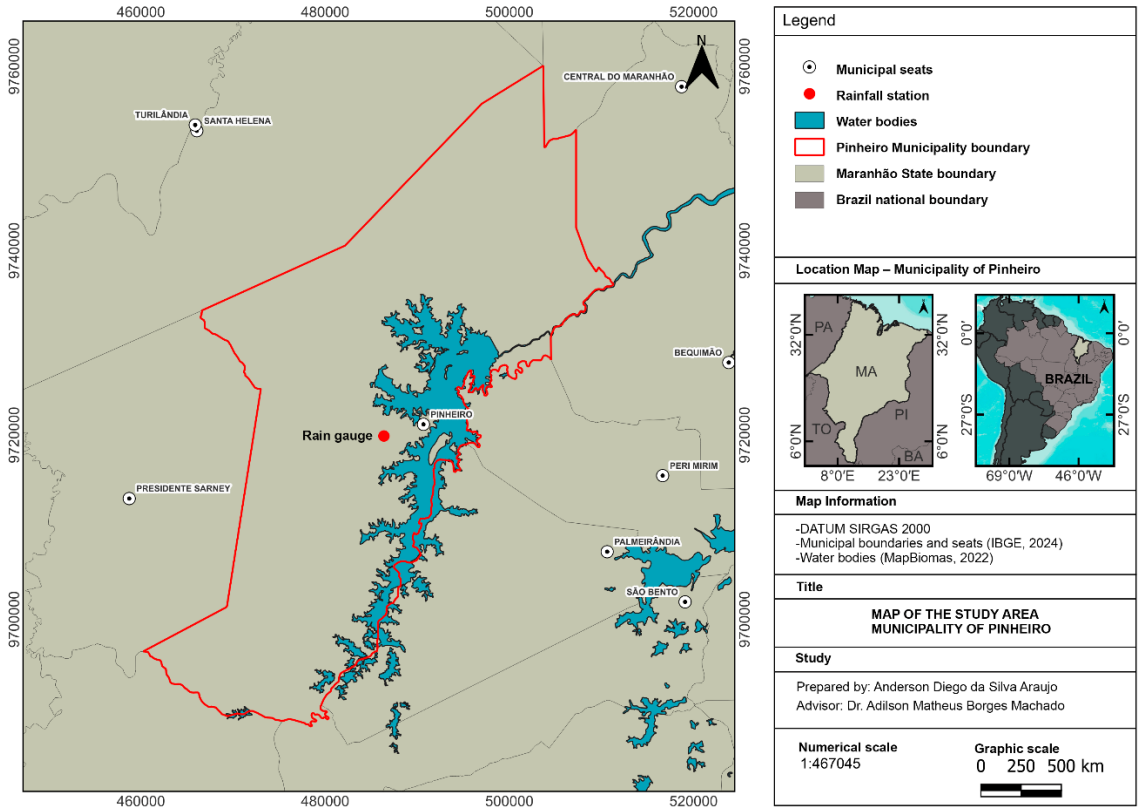
2.1 Study Area

The study area is located in the municipality of Pinheiro, within the Baixada Maranhense microregion, characterized by climatic conditions typical of tropical regions, with a hot and humid tropical climate of type Aw, according to the Köppen–Geiger classification (Lima et al., 2024). This climatic pattern, predominant in the state of Maranhão, is marked by high temperatures throughout the year and a pronounced rainfall seasonality, with a higher concentration of rainfall

in the first months of the year and a reduction in precipitation volumes in the second half of the year.

Pinheiro is located at the coordinates 2°31′16″ S latitude and 45°04′22″ W longitude (Figure 1), with an average altitude of approximately 8 m above sea level and a territorial area of 1,465.597 km² (IBGE, 2022). Within the environmental context of the Baixada Maranhense, the municipality is part of a region that records mean annual temperatures between 25 °C and 26.5 °C and annual rainfall ranging from 1,700 mm to 1,900 mm. These conditions favor the development of open fields, floodplain forests, and periodically flooded areas, which are characteristic elements of regional wetland environments (Araújo et al., 2019).

Figure 1 – Location of the study area in Pinheiro, Baixada Maranhense, Maranhão, Brazil.



Source: Author's own elaboration.

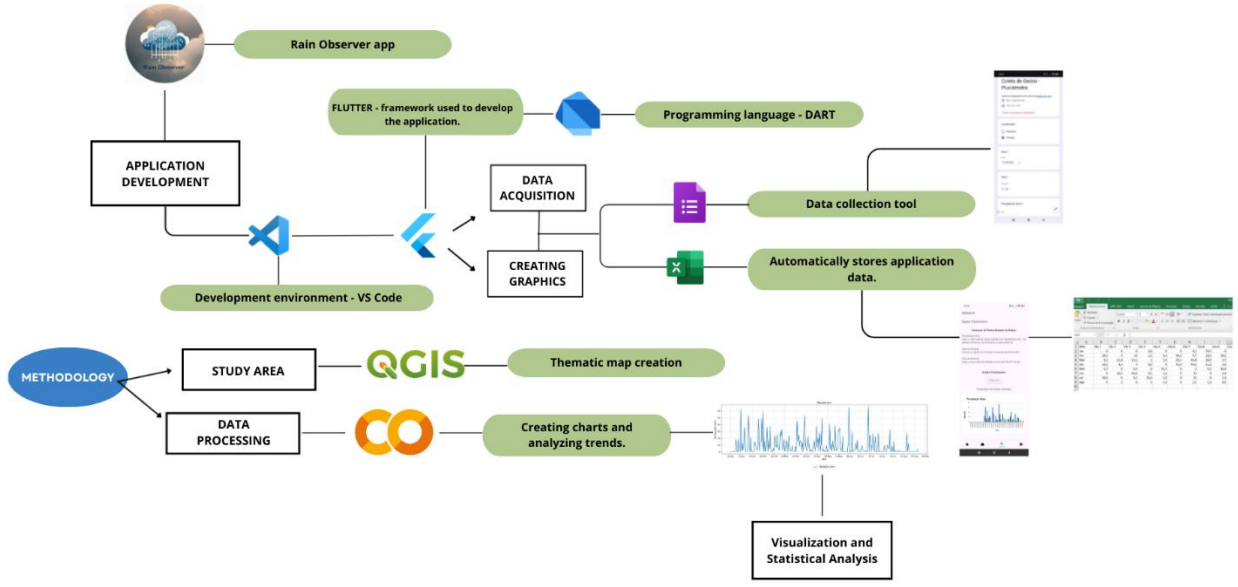
2.2 Development of the Application and Data Collection Procedures

Before the beginning of data collection, the educational application Rain Observer was developed, a multiplatform solution created using the Flutter framework to facilitate the recording, organization, and visualization of pluviometric data. The application allows the input of measurements and is integrated with Google Forms and Excel, enabling data monitoring through automatically generated graphs within the application, replacing the use of manual spreadsheets. The methodological workflow adopted in this study is summarized in the flowchart presented in Figure 2.

The development was structured in planning, implementation, and integration stages with external services, resulting in a simple interface organized into four main screens: Home, Rain Gauge, Data, and Help, prioritizing principles of usability and accessibility. Graph visualization occurs through automatic image updates, enabling near real-time monitoring of data collection.

After development, data collection was conducted according to the protocols of the GLOBE program, using a conventional rain gauge installed at the Federal University of Maranhão Campus Pinheiro. Measurements were taken daily at 5:00 p.m. by students and recorded directly in the application from January to August 2025, enabling the acquisition of a consistent data series and the identification of seasonal precipitation patterns.

Figure 2 – Methodological workflow



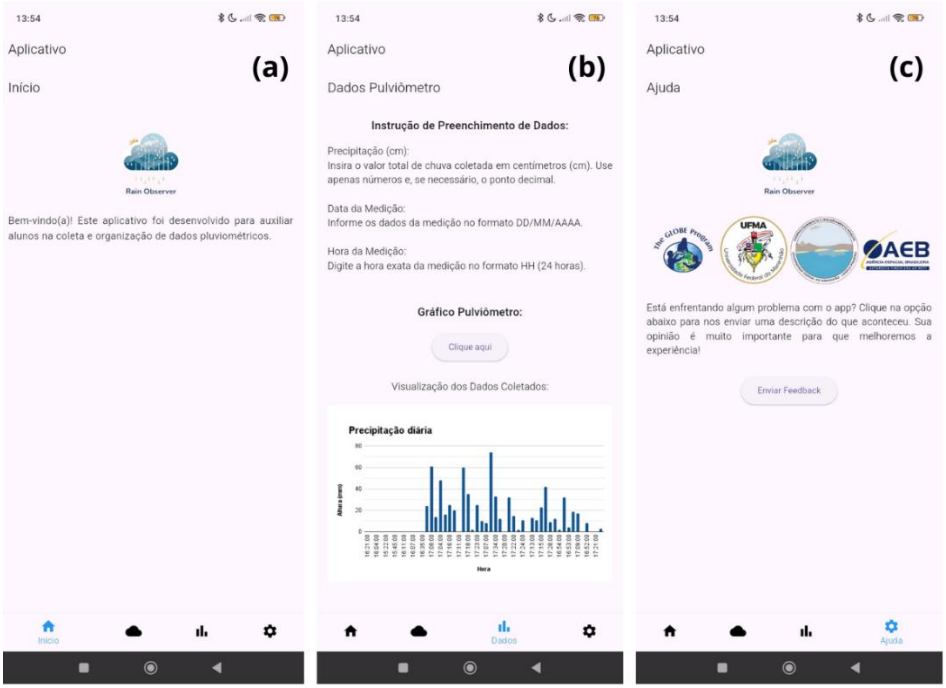
Source: Author's own elaboration.

For the spatial characterization of the study area, QGIS software was used for processing, integrating, and organizing geospatial data, enabling the delimitation of the analyzed area and the visualization of its main spatial characteristics. The daily mean precipitation graph was produced in the Google Colab environment, where pluviometric data were processed and analyzed, allowing the generation of visualizations that supported the interpretation of precipitation variability throughout the studied period.

3. Results and data

The implementation of the application resulted in advances in the quality, efficiency, and standardization of pluviometric precipitation recording (Figure 3), making the data collection process more reliable and reproducible in elementary and high schools. The use of technology enabled the organization, storage, and efficient retrieval of data, contributing to the construction of local historical precipitation series, which are fundamental for future analyses of climate variability in the municipality of Pinheiro.

Figure 3 – **(a)**, **(b)**, and **(c)** Application interface.



Source: Author's own elaboration.

In the educational context, the main objective of the project is to develop the application and train elementary and high school students in its use, generating greater student engagement in activities related to Science and Geography subjects. Direct contact with environmental phenomena, combined with the use of the application, stimulates curiosity, critical thinking, and socio-environmental responsibility in the region.

In parallel, during data collection and application programming, whose procedures for rain gauge installation and reading of accumulated precipitation are shown in Figure 4, the collaboration of undergraduate students in data recording at the Pinheiro Campus was observed, strengthening the development of socio-emotional competencies such as cooperation, responsibility, and protagonism. In addition, data storage in the application represents a relevant pedagogical advance, as it stimulates the development of technological competencies, such as data organization, use of digital tools, and initial notions of programming. In an integrated manner, students who participate in the stages of the scientific process, from data collection to analysis, may develop skills in interpretation, identification of climate trends, and scientific communication.

Figure 4 – (a) and (b) Rain gauge installation; (c) and (d) Reading of accumulated precipitation.

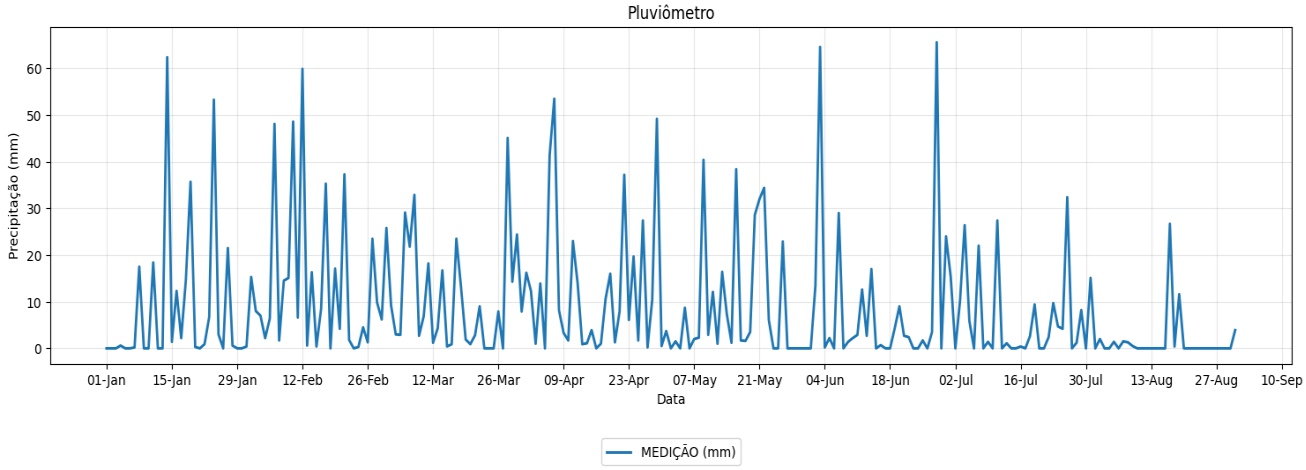
Source: Author's own elaboration.

3.1 Analysis of Daily Mean Precipitation

Graph 1 shows high variability in daily precipitation, with an average of 9.1 mm/day, resulting from the alternation between numerous dry days or days with low rainfall volumes and a few high-intensity events. The highest rainfall volumes are concentrated between January and April, when the main pluviometric peaks occur, accounting for a significant portion of the total precipitation. In May and June, rainfall still occurs, but with lower frequency and intensity. From

July onward, a marked reduction in precipitation is observed, with a predominance of dry days, especially in July and August. Overall, the irregular distribution of rainfall, concentrated on a few days, reflects a typical pattern of tropical climate regions, associated with convective events.

Graph 1. Daily mean precipitation recorded by the rain gauge.



Source: Author's own elaboration.

4. Discussion

Based on the data organized and systematized through the application, the analysis of Graph 1, which represents the mean daily precipitation of 9.1 mm/day, indicates high temporal variability, characterized by the alternation between numerous days with low rainfall volumes or no rainfall and a few high-intensity events. This behavior indicates that the daily mean masks the strong concentration of precipitation in episodic events, which exert a significant influence on the total accumulated rainfall during the analyzed period.

The observed daily peaks reinforce the episodic and irregular nature of rainfall, a typical pattern of regions under the influence of a tropical climate, where precipitation is predominantly associated with short-duration convective systems. According to the IPCC (2023), this type of rainfall regime may tend to exhibit a higher frequency of extreme events, even without significant changes in mean values, which is consistent with the results presented in the graph.

Overall, the results shown in Graph 1 reinforce the need for detailed historical time series to understand local climate variability and to support planning and adaptation actions in the context

of climate change. In this context, the daily variability recorded in this study highlights the importance of continuous in situ monitoring, since analyses based only on monthly or annual averages may underestimate the occurrence of extreme precipitation events. Recent studies indicate that the intensification of these events has direct implications for hydrological dynamics and socio-environmental risks in tropical areas (Baek et al., 2023).

The use of the application for data recording indicates that the integration between digital technology and citizen science in the school environment constitutes an effective strategy for strengthening the teaching of Science and Geography. The use of the application may promote greater student engagement in pluviometric monitoring activities, stimulating active participation, critical thinking, and meaningful learning, as also observed by Rodrigues et al. (2022).

The inclusion of citizen science in the school context brings scientific knowledge closer to students' reality by enabling the practical application of concepts related to climate and rainfall variability. This approach contributes to consolidating environmental education as a structural axis of student training, in line with the discussions of Oliveira and Santos (2023), by linking scientific investigation to local environmental problems.

In addition to optimizing data systematization, the tool contributes to greater student interest and better understanding of climatology-related content, as highlighted by Mendes and Barros (2023). The application may also act as a link between field practice and data analysis, characterizing an interdisciplinary learning environment, in accordance with Ghilardi-Lopes et al. (2023) and Peña-Rodriguez et al. (2022).

5. Conclusion

The development and application of the educational application Rain Observer proved to be effective in improving the process of collecting, organizing, and analyzing precipitation data in the municipality of Pinheiro, Maranhão, Brazil. In this sense, the automation of pluviometric data recording enabled the creation of a continuous and reliable database, enhancing data quality and facilitating local-scale climate analyses.

Based on the data systematized by the application, the analysis of daily precipitation revealed a rainfall regime marked by temporal variability, characterized by the concentration of

rainfall volumes in a few intense events, especially during the first months of the analyzed period. Thus, the results reinforce the importance of daily monitoring for understanding local climate dynamics and for supporting environmental planning and management actions.

Beyond technical aspects, from an educational perspective, the project has the potential to contribute to the engagement of elementary and high school students in the Baixada Maranhense and Maranhão Coastal Zone regions, promoting active participation in scientific practices, developing technological competencies, and strengthening environmental education. Therefore, the integration of science, technology, and education, combined with the principles of citizen science, constitutes a consistent strategy for training critical, aware citizens prepared to understand and address the challenges associated with climate variability and global climate change.

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Peña-Rodríguez, J., Salgado-Meza, P. A., Asorey, H., Núñez, L. A., Núñez-Castiñeyra, A., Sarmiento-Cano, C., & Suárez-Durán, M. (2022). *RACIMO@Bucaramanga: A citizen science project on data science and climate awareness*. arXiv. https://arxiv.org/abs/2203.05431

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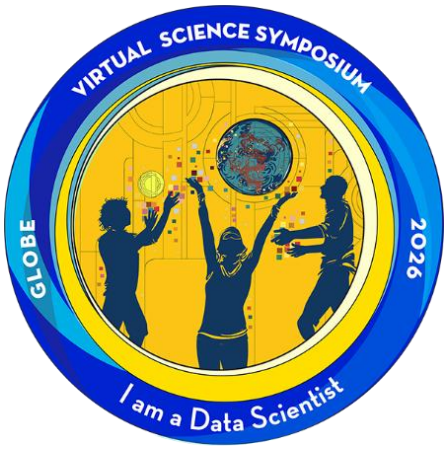
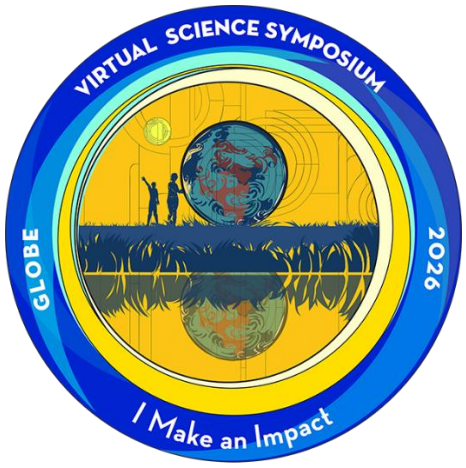
7. Badges

	The project involved the collection and organization of precipitation data within the atmospheric sphere, obtained through daily measurements using a rain gauge, in accordance with the GLOBE Precipitation Protocol, which is part of the Atmosphere study area. The information was recorded in a digital environment, enabling the construction of a structured dataset on precipitation variability in the municipality of Pinheiro, Maranhão. The pluviometric data were analyzed to identify temporal patterns, daily variations, and characteristics of the local rainfall regime, allowing the interpretation of atmospheric processes at the local scale. Considering the limitations related to the data collection period and the spatial scale of the measurements, the project demonstrated the critical and systematic use of environmental data to investigate Earth system phenomena.
	The project was collaboratively developed by undergraduate students from the Federal University of Maranhão (UFMA), with a focus on developing an educational application for recording pluviometric data in Pinheiro, State of Maranhão, Brazil. The participatory approach integrated scientific, technological, and educational knowledge, promoting student engagement in local climate monitoring. The undergraduate students were involved in all stages of the project, from application development to the systematic collection and recording of precipitation data, following the GLOBE Precipitation Protocol. The initiative demonstrated the potential of digital technologies and citizen science for the production of local climate data, the strengthening of students' scientific and socio-environmental training, and the support of environmental planning and water resource management, also highlighting the importance of community participation in environmental monitoring.

	The project was conceived based on a local demand associated with the absence of systematized pluviometric records, a condition that limits the understanding of climate variability and environmental planning in the municipality. The initiative establishes direct connections between a local problem and broader environmental challenges related to climate monitoring and water resource management. The proposal contributes to strengthening precipitation monitoring by promoting the use of a digital tool designed for standardized and continuous recording of pluviometric data. The application facilitates data organization, increases the reliability of records, and creates conditions for the construction of local historical time series, with the potential to support territorial planning actions, environmental management, and adaptation to climate variability. In the educational and social context, the project may stimulate active student participation in citizen science practices, integrating technology, field observations, and environmental data analysis. This approach contributed to the development of scientific and technological competencies, increased environmental awareness, and encouraged community involvement in local environmental monitoring.