

# Types of Educational Tools and Local Conditions for Implementing Education for Sustainable Development in the Itasy Region, Madagascar

Andriamasinoro Nambinintsoa Nelly, Rakotoarivelo Anselme, Andriatahiana Fanomezantsoa Michella

Université de Toamasina, Madagascar  
Email address: randrianarisoanelly@gmail.com

**Abstract**— This article analyzes the typology of pedagogical arrangements and the territorial conditions for the implementation of Education for Sustainable Development (ESD) in the Itasy region of Madagascar, based on a multivariate statistical analysis applied to survey data collected from teachers. The determination of the optimal number of pedagogical profiles relies on hierarchical clustering combined with internal validation indicators, revealing a clear break in aggregation distances around 14–15 and leading to the identification of three interpretable profiles, despite a statistically optimal solution observed for two clusters (silhouette coefficient = 0.42). The territorial distribution highlights marked contrasts between districts, with a predominance of standard or weakly contextualized arrangements in Arivonimamo (47%), a strong representation of the project-based approach in Miarinarivo (41%), and a concentration of contextualized and plurilingual arrangements in Soavinandriana (44%). Levels of diversity integration differ significantly across profiles, reaching an average score of 3.97 for contextualized and plurilingual arrangements, compared with 3.42 for the project-based approach and 2.57 for standard arrangements. The analysis of drivers and barriers reveals persistent constraints related to resources and instructional time (scores < 2.7), while highlighting the moderating role of teacher training and institutional support (scores ranging between 3.29 and 3.34). These results confirm that the implementation of ESD depends on territorial configurations combining pedagogical profiles, institutional resources, and sociocultural contexts.

**Keywords**— Education for Sustainable Development; Madagascar; pedagogical arrangements; territorial analysis; typology.

## I. INTRODUCTION

Education for sustainable development (ESD) has gradually established itself as a structured educational framework aimed at linking the environmental, social, and economic dimensions of development in contemporary education systems [1]. Beyond its inclusion in official curricula, ESD raises questions about the practicalities of its implementation, particularly in terms of the pedagogical arrangement used by teachers and the institutional and territorial conditions in which these methods take shape [2]. Several studies have highlighted that the effectiveness of ESD depends less on institutional requirements alone than on the ability of educational actors to adapt teaching practices to local contexts and the sociocultural realities of different regions [3]. In the context of countries in the Global South, and more particularly in sub-Saharan Africa, these challenges are exacerbated by the linguistic, cultural, and

socioeconomic diversity of school populations, as well as by marked regional disparities in educational resources and teacher training [4]. In Madagascar, schools are key mediators between national education policies and local dynamics, where sociocultural diversity can be both a factor of complexity and a potential lever for the appropriation of Sustainable Development Goals [5]. The Itasy region is a prime example of these tensions, combining marked territorial contrasts, heterogeneous institutional contexts, and varied forms of community roots [6].

In this context, few empirical studies have proposed an integrated statistical analysis that characterizes both the profiles of ESD educational programs, their territorial distribution, and the levers or obstacles associated with their implementation. Using a typological approach and multivariate methods, this article aims to fill this gap by analyzing the educational and territorial configurations of ESD in the Itasy region of Madagascar. It thus forms part of an analytical perspective aimed at better understanding the mechanisms by which territorial and institutional conditions influence the diversity of educational practices and, ultimately, the effective implementation of education for sustainable development [7].

## II. MATERIALS AND METHODS

This research is based on a mixed methodological approach combining quantitative field research and documentary analysis in order to analyze the profiles of educational programs and the territorial conditions for implementing education for sustainable development in the Itasy region of Madagascar. The spatial framework of the study was defined on the basis of the official administrative division of regions, districts, and municipalities, which was used as a reference for structuring the sample and aggregating data at the territorial level [8]. The demographic, socioeconomic, and territorial characteristics of the Itasy region were documented using the regional monograph published by the National Institute of Statistics, which provides an essential contextual framework for interpreting the contrasts observed between districts [9].

Field data was collected from teachers working in primary, middle, and high schools using standardized questionnaires administered in the region's three districts. The data collection

tools gathered information on the institutional contexts of the schools, the teaching practices used in education for sustainable development, and the levers and obstacles perceived by educational stakeholders. Teaching methods were measured using ordinal frequency scales ranging from 0 to 4, while the implementation of education for sustainable development and the drivers or obstacles were assessed on Likert scales from 1 to 5. Open-ended responses on the main drivers and barriers were coded thematically after the fact to produce statistically usable variables, in accordance with methodological practices in education sciences and the sociology of education [10].

The statistical analysis was conducted using a progressive and exploratory approach. Advanced descriptive statistics were first produced to characterize the distribution of variables and compare average scores across districts and territorial contexts. These analyses were supplemented by association tests adapted to the nature of the data, including Chi<sup>2</sup> tests for categorical variables and parametric or non-parametric tests for score comparisons. The construction of a typology of teaching methods was based on a combination of multivariate methods, including ascending hierarchical classification using Ward's method, followed by consolidation using k-means, in order to identify homogeneous profiles of teaching practices. The robustness of the typology was assessed using internal validation indicators such as the silhouette coefficient and the Calinski-Harabasz index, which are widely used in classification analyses applied to educational data [11].

In order to analyze the relationships between pedagogical profiles, integration of sociocultural diversity, and territorial conditions of implementation, multivariate regression models were estimated, incorporating interaction terms to test the moderating effect of certain institutional levers. When the data structure presented a hierarchical interconnection, particularly with teachers grouped within schools and districts, multilevel mixed-effects models were used to distinguish the effects attributable to the different levels of analysis. All statistical processing and graphical visualizations were performed in Python, within the Jupyter Notebook environment integrated into the Anaconda distribution. The pandas and numpy libraries were used for data preparation and management, scikit-learn, scipy, and statsmodels for statistical analyses and models, and matplotlib for the production of scientific graphics, ensuring the reproducibility and traceability of the analyses [12].

### III. RESULTS AND DISCUSSIONS

#### A. Determination and validation of the optimal number of educational device profiles

The following figure 1 - 2 presents the results of the classification analysis aimed at determining the optimal number of educational device profiles, combining hierarchical cluster exploration and internal validation indicators to ensure the robustness and interpretability of the selected typology.

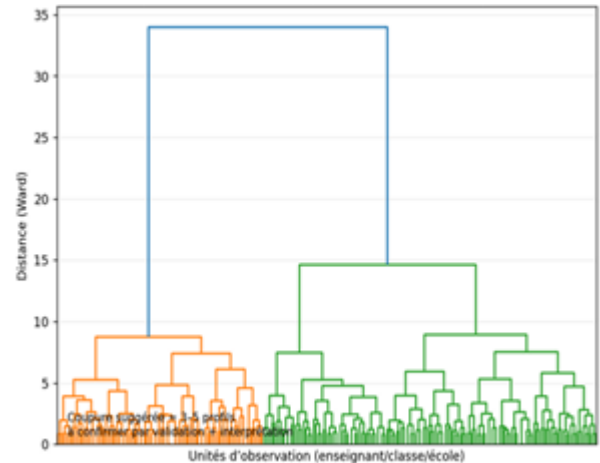


Fig. 1. Determining the number of profiles

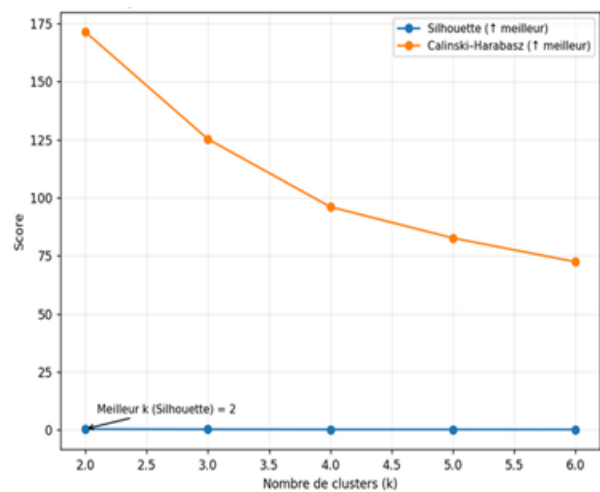


Fig. 2. Validation of the optimal number of educational device profiles

#### Interpretation

Hierarchical analysis using Ward's method highlights a gradual structuring of the observation units, with a marked break in the aggregation distance from a threshold of around 14 to 15 units. This break suggests the existence of a limited number of coherent groupings, with the dendrogram cut-off indicating a plausible solution of between three and five profiles. However, the configuration observed shows that beyond three groupings, intra-group distances increase less dramatically, which limits the readability and interpretative relevance of more complex solutions. Internal validation indicators confirm this reading. The silhouette coefficient reaches its maximum value for a two-cluster solution, with a score of around 0.42, reflecting a clear separation between groups and good internal cohesion. On the other hand, this coefficient decreases gradually as the number of clusters increases, reaching values close to 0.25 for four clusters and below 0.20 for six clusters, indicating a loss of partition quality. Convergenly, the Calinski-Harabasz index decreases sharply between two and three clusters, falling from around 170 to 125, then continues to decline steadily to values close to 70 for six clusters. Taken together, these results indicate that a two- or three-profile solution offers the best compromise between statistical quality and interpretability. However, the

final choice of a three-profile solution appears justified by the desire to reconcile the robustness of the validation indicators with a more detailed analytical reading of the educational systems, making it possible to distinguish between different configurations while maintaining a statistically consistent structure.

**B. Territorial distribution of profiles of pedagogical devices and levels of integration of diversity**

The figure below shows, on the one hand, the distribution of educational profiles identified according to districts in the Itasy region and, on the other hand, the average levels of sociocultural diversity integration associated with each of these profiles, in order to shed light on territorial variations and qualitative differences between the ways in which education for sustainable development is implemented.

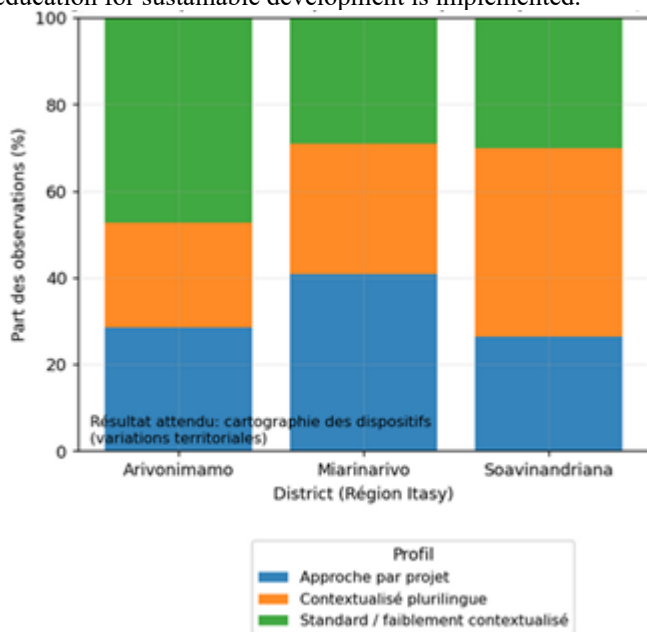


Fig. 3. Distribution of device profiles by district (%)

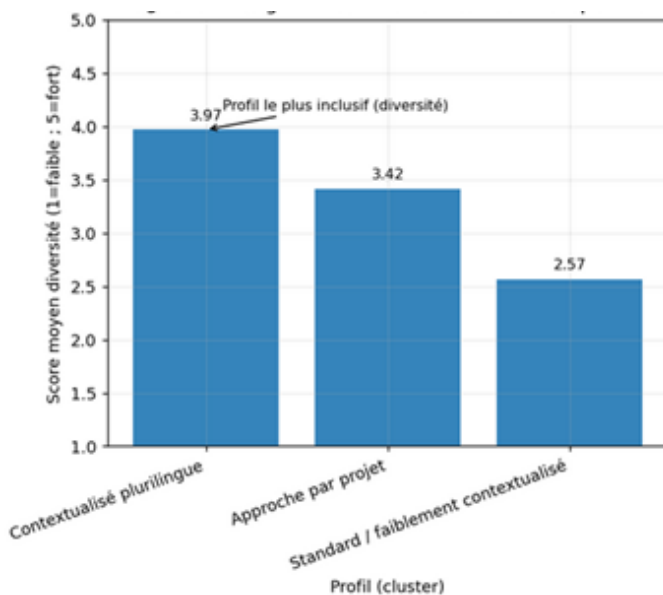


Fig. 4. Integrating diversity based on profiles

**Interpretation**

The distribution of teaching methods reveals significant regional contrasts between districts in the Itasy region. In Arivonimamo, standard or weakly contextualized methods remain predominant, accounting for around 47% of observations, while project-based approaches and contextualized and multilingual methods account for 28% and 25% of observed situations, respectively. This configuration suggests a predominance of undifferentiated teaching practices, despite the significant presence of more active or contextualized approaches. In Miarinarivo, the structure appears significantly different, with a strong representation of the project-based approach, which accounts for 41%, compared to 30% for contextualized and multilingual approaches and 29% for standard approaches. This distribution reflects a teaching dynamic that is more oriented towards active practices, while maintaining a diversity of integration methods. In Soavinandriana, contextualized and multilingual approaches occupy a central place, representing around 44% of observations, ahead of standard approaches, estimated at 30%, and project-based approaches, limited to 26%. This regional profile reflects a stronger anchoring of teaching practices in local sociocultural realities. Analysis of average levels of diversity integration confirms these qualitative contrasts between profiles. Contextualized and multilingual approaches scored highest, with an average value of 3.97 on a scale of 1 to 5, reflecting substantial consideration of linguistic, cultural, and community dimensions. Project-based approaches show an intermediate level of diversity integration, with an average score of 3.42, indicating a real but uneven sensitivity to sociocultural contexts. In contrast, standard or weakly contextualized programs have the lowest score, at 2.57, revealing limited integration of diversity into teaching practices. Taken together, these results show that the territorial distribution of teaching program profiles is closely linked to their ability to integrate sociocultural diversity. They highlight that the territories in which contextualized and multilingual approaches are most prevalent are also those where the integration of diversity appears to be highest, confirming the central role of pedagogical contextualization in the differentiated and inclusive implementation of education for sustainable development.

**C. Levers and obstacles to the implementation of ESD: territorial comparisons and factorial structuring**

The figure below presents a cross-analysis of the drivers and barriers to implementing education for sustainable development in the districts of the Itasy region, combining a summary representation of the average scores by dimension and a factorial projection aimed at identifying characteristic groupings of factors according to territorial contexts.

**Interpretation**

Analysis of the average scores for drivers and barriers reveals different regional profiles within the Itasy region. The three districts have relatively low and consistent levels of teaching resources and time available in the curricula, with scores ranging from 2.49 to 2.64, indicating persistent structural constraints. Conversely, the dimensions relating to

teacher training and institutional support appear to be more significant levers.

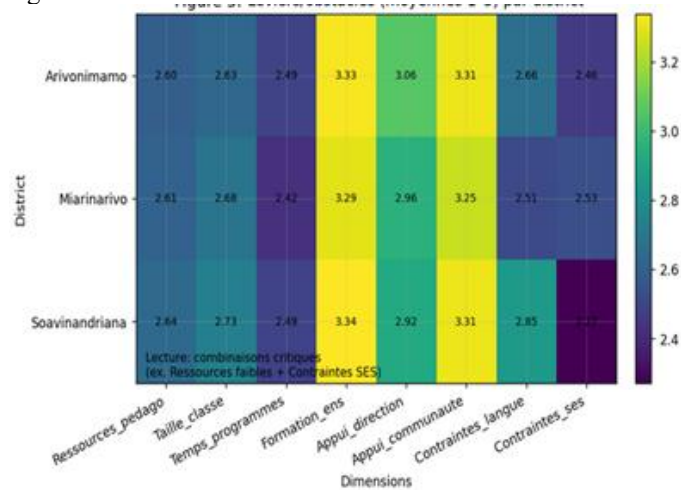


Fig. 5. Levers and obstacles to the implementation of education for sustainable development

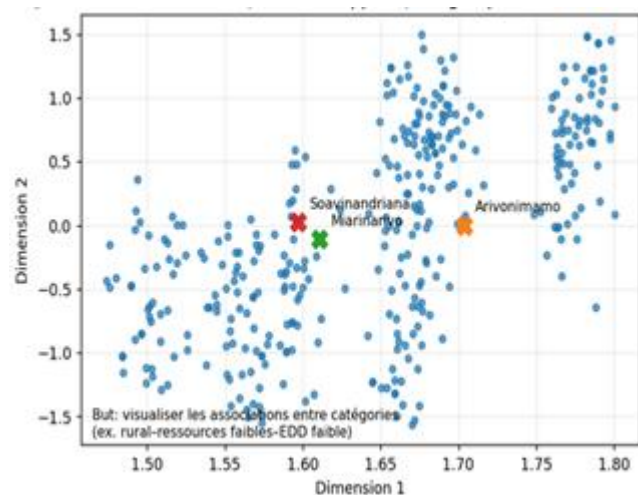


Fig. 6. territorial comparisons and factor structuring

Teacher training scores reach 3.33 in Arivonimamo, 3.29 in Miarinarivo, and 3.34 in Soavinandriana, while support from management and the community is around 3.0 to 3.3 in all districts, reflecting moderate but real institutional and social support. More marked differences appear with regard to linguistic and socioeconomic constraints. Soavinandriana stands out with a relatively high score for linguistic constraints, estimated at 2.85, suggesting a more pronounced presence of challenges related to the language of instruction, while socioeconomic constraints are most pronounced there, with a score of 2.27, compared to 2.46 in Arivonimamo and 2.53 in Miarinarivo. These results confirm the weight of socioeconomic factors in the most rural areas with the fewest institutional resources. Factor projection complements this interpretation by highlighting coherent groupings of drivers and obstacles. The observations associated with Arivonimamo are mainly on the positive side of the first dimension, reflecting a combination of relative institutional support and moderate constraints, while Miarinarivo occupies an intermediate position, reflecting a balance between

institutional resources and structural constraints. Soavinandriana appears closer to configurations combining low resources and more pronounced socioeconomic and linguistic constraints, suggesting an accumulation of factors likely to limit the effective implementation of education for sustainable development. Taken together, these results show that the levers and obstacles to the integration of education for sustainable development are not distributed in isolation, but tend to cluster in specific territorial configurations. They emphasize that the ability of schools to implement appropriate educational programs depends less on a single factor than on a combination of institutional resources, community support, and sociocultural constraints, thus confirming the need for territorialized and differentiated approaches to strengthen the effectiveness and equity of educational policies in the area of ESD.

*D. Summary of statistical results on educational profiles, their geographical distribution, and the drivers/barriers to ESD in the Itasy region*

Table 1 below presents a summary of the statistical models, highlighting a robust and consistent structure for sustainable development education programs in the Itasy region. The classification analysis reveals a clear break in the hierarchical aggregation at a distance threshold of around 14 to 15, suggesting the existence of a limited number of distinct profiles. Although internal validation indicators point to a two-cluster solution as statistically optimal, with a silhouette coefficient of 0.42 and a Calinski-Harabasz index close to 170, the choice of a three-profile solution appears methodologically relevant in order to preserve a more detailed analytical interpretation of the educational practices observed.

*Interpretation*

The geographical distribution of profiles confirms the existence of different configurations between districts. Miarinarivo is characterized by a strong representation of the project-based approach, which accounts for 41% of observations, while Soavinandriana is distinguished by a predominance of contextualized and multilingual systems, representing 44% of the situations observed. Conversely, Arivonimamo remains predominantly associated with standard or weakly contextualized approaches, which account for 47%. These quantitative differences translate into significant gaps in the integration of sociocultural diversity, with contextualized and multilingual approaches scoring the highest average, at 3.97, compared to 3.42 for the project-based approach and only 2.57 for standard approaches. The analysis of levers and obstacles complements this reading by showing that structural constraints, particularly in terms of teaching resources and time in the curricula, remain low overall and consistent across districts, with scores below 2.7. On the other hand, teacher training and institutional support appear to be moderately high levers, with scores between 3.29 and 3.34. The factorial structure highlights coherent territorial groupings, combining low resources with more pronounced linguistic and socioeconomic constraints in the most rural districts. Taken together, these results show that the implementation of education for sustainable development is based on complex

configurations where educational profiles, territorial contexts, and combinations of levers and obstacles interact closely,

highlighting the need for differentiated and territorialized approaches.

TABLE I. Summary of Statistical Results on Educational Profiles, Territorial Distribution, and Drivers and Barriers to ESD in the Itasy Region.

Analysis axis	Key statistical indicators	Main results
<b>Determination of the number of profiles</b>	Classification method	CAH (Ward) + k-means
	Break distance (CAH)	≈ 14–15
	Number of profiles explored	2 to 6
	Silhouette coefficient (max.)	0,42 for k = 2
	Calinski-Harabasz index (max.)	≈ 170 for k = 2
	Solution selected	3 profiles (robustness/interpretability compromise)
<b>Territorial distribution of profiles</b>	Project-based approach (%)	Arivonimamo : 28 ; Miarinarivo : 41 ; Soavinandriana : 26
	Multilingual contextualization (%)	Arivonimamo : 25 ; Miarinarivo : 30 ; Soavinandriana : 44
	Standard/lowly contextualized (%)	Arivonimamo : 47 ; Miarinarivo : 29 ; Soavinandriana : 30
	Average diversity integration score (1–5)	Multilingual contextualized: 3,97 ; Project-based approach: 3,42 ; Standard : 2,57
<b>Levers and obstacles (territories)</b>	Pedagogical resources (1–5)	2,49 to 2,64
	Teacher training (1–5)	3,29 to 3,34
	Management/community support (1–5)	2,92 to 3,31
	Linguistic constraints (1–5)	2,51 to 2,85
	Socioeconomic constraints (1–5)	2,27 to 2,53
	Factor structuring	Coherent groupings of levers/barriers by district

IV. DISCUSSION

The results of this study confirm that the implementation of education for sustainable development in the Itasy region is based on differentiated pedagogical and territorial configurations, structured around distinct profiles of specific mechanisms and combinations of levers and obstacles. The typology identified highlights that contextualized and multilingual educational systems are associated with the highest levels of diversity integration and ESD implementation, while standardized systems remain more limited in their ability to respond to the complexity of sociocultural contexts. This finding is consistent with research highlighting that the effectiveness of ESD largely depends on its territorial anchoring and the consideration of local realities in educational practices [13].

The geographical distribution of profiles observed in the Itasy region highlights contrasting dynamics between districts, confirming that institutional and community contexts play a structuring role in educational choices. Studies conducted in other educational contexts also show that territories characterized by strong community engagement and a valuing of local knowledge are more conducive to the emergence of active and inclusive teaching practices in ESD [14]. Conversely, territories with more limited institutional resources tend to maintain more standardized practices, despite the presence of incentive-based educational policies.

Analysis of the drivers and barriers also confirms that sociocultural diversity is not in itself a clear explanatory factor for the implementation of ESD. The results show that teacher training and institutional support play a key moderating role, enabling diversity to be transformed into an educational resource rather than a constraint. This interaction between diversity, pedagogical approaches, and institutional conditions is widely documented in the literature, which emphasizes the importance of professional and organizational support to foster pedagogical innovation and strengthen educational equity in the context of ESD [15]. From this perspective, the results

obtained in Itasy contribute to enriching comparative analyses of ESD in territorialized contexts by providing empirical evidence from a multivariate statistical approach at the regional level.

V. CONCLUSION

This research highlighted the diversity of educational approaches and regional conditions for implementing education for sustainable development in the Itasy region of Madagascar. Statistical analysis revealed the existence of distinct educational profiles, structured around varying degrees of contextualization, participation, and integration of sociocultural diversity. These profiles are not evenly distributed across the region, but reflect specific territorial configurations linked to institutional contexts, community dynamics, and the resources available in schools. The results show that contextualized and multilingual pedagogical approaches are associated with the highest levels of diversity integration and implementation of education for sustainable development, while more standardized approaches remain limited in their ability to respond to local sociocultural realities. Furthermore, analysis of the drivers and barriers highlights that teacher training, institutional support, and the involvement of local communities play a decisive role in transforming diversity into an educational resource, while structural constraints related to resources, time, and socioeconomic conditions continue to weigh on educational practices.

Overall, this study highlights the importance of territorialized and differentiated approaches to enhancing the effectiveness and equity of education for sustainable development. It underscores the need for education policies that recognize the diversity of local contexts and support pedagogical innovation in order to promote the sustainable and adapted implementation of ESD in comparable educational contexts.

REFERENCES

- [1] UNESCO, “Éducation au développement durable : objectifs d'apprentissage,” Paris, France: UNESCO, 2017.
- [2] D. Tilbury, *Education for Sustainable Development: An Expert Review of Processes and Learning*. Paris, France: UNESCO, 2011.
- [3] J.-M. Lange, “L'éducation au développement durable : enjeux et perspectives pédagogiques,” *Revue française de pédagogie*, vol. 170, pp. 55–68, 2010.
- [4] European Scientific Journal, “Education for Sustainable Development and Local Contexts in Developing Countries,” *European Scientific Journal*, vol. 18, no. 25, 2022.
- [5] Le Sociographe, “Éducation, territoires et développement durable,” *Le Sociographe*, vol. 29, pp. 27–38, 2009.
- [6] INSTAT and CREAM, “Monographie de la région Itasy,” Institut National de la Statistique, Antananarivo, Madagascar, Rep., 2013.
- [7] Revue internationale d'éducation de Sèvres, “L'éducation au développement durable : approches territorialisées et comparaisons internationales,” *Revue internationale d'éducation de Sèvres*, no. 90, 2022.
- [8] MadaCamp, “Regions, Districts and Communes of Madagascar,” 2023. Available: [https://www.madacamp.com/Regions\\_Districts\\_and\\_Communes\\_of\\_Madagascar](https://www.madacamp.com/Regions_Districts_and_Communes_of_Madagascar)
- [9] INSTAT and CREAM, “Monographie de la région Itasy,” Institut National de la Statistique, Antananarivo, Madagascar, Rep., 2013. Available: <https://www.instat.mg/p/cream-monographie-region-itasy-fevrier-2013>
- [10] Le Sociographe, “Éducation, territoires et développement durable,” *Le Sociographe*, vol. 29, pp. 27–38, 2009.
- [11] B. S. Everitt, S. Landau, M. Leese, and D. Stahl, *Cluster Analysis*, 5th ed. Chichester, UK: Wiley, 2011.
- [12] F. Pedregosa, G. Varoquaux, A. Gramfort, V. Michel, B. Thirion, O. Grisel, M. Blondel, P. Prettenhofer, R. Weiss, V. Dubourg, J. Vanderplas, A. Passos, D. Cournapeau, M. Brucher, M. Perrot, and É. Duchesnay, “Scikit-learn: Machine Learning in Python,” *Journal of Machine Learning Research*, vol. 12, pp. 2825–2830, 2011.
- [13] Revue internationale d'éducation de Sèvres, “L'éducation au développement durable : approches territorialisées et comparaisons internationales,” *Revue internationale d'éducation de Sèvres*, no. 90, 2022. Available: <https://journals.openedition.org/ries/15105>.
- [14] Le Sociographe, “Éducation, territoires et développement durable,” *Le Sociographe*, vol. 29, pp. 27–38, 2009. Available: <https://shs.cairn.info/revue-le-sociographe-2009-2-page-27>
- [15] C. Desvignes, “L'éducation au développement durable, source de motivation pour les élèves,” M.S. thesis, Department of Education Sciences, University of Bordeaux, Bordeaux, France, 2021. Available: <https://dumas.ccsd.cnrs.fr/dumas-03702666v1/document>