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Opportunities Arising from Data Orchestration: A Case Study of the Educational Data Ecosystem of a Brazilian State.

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1 INTRODUCTION

The evolution of the digital economy has encouraged the transformation of governments, prompting the adoption of information systems to digitize processes and broaden the scope of services offered to the population (Viana, 2021). As a result of this transformation, there has been a significant increase in the generation of data concerning the activities and services offered by governments, including those in the fields of health, security, and education (Gao *et al.*, 2023). In this regard, the accessibility of information enables better coordination for the analysis and monitoring of public policies, which rely on data to evaluate and oversee the attainment of their objectives (Matheus *et al.*, 2020).

Among these initiatives, those concerning education are particularly noteworthy. In Brazil, as outlined in the National Education Plan (Brasil, 2014), collaborative efforts across federal, state, and municipal levels are indispensable for achieving educational goals. Public actors must engage in coordinated efforts to effectively implement educational policies. Access to comprehensive data and metrics is essential for facilitating this coordination, as these resources provide critical evidence on educational indicators, supporting public managers in making informed decisions. By leveraging educational metrics, public managers can develop targeted strategies that address specific challenges within the education system. Additionally, the use of data fosters transparency and accountability, ensuring that educational policies are implemented in a manner responsive to the needs of the population (Gao *et al.*, 2023).

From a data perspective, a concept emerging in the literature is “data ecosystems”. According to Gelhaar *et al.* (2021), data ecosystems consist of an environment with numerous actors where continuous data generation occurs through their interrelationships. In the context of education, it represents the relationships between schools, governments, suppliers, civil society, and other stakeholders in the educational process. From the perspective of technology, ecosystems play a crucial role in supplying data for monitoring and analysis, including educational data. This catalyzes enhancing transparency, social control, and the ongoing enhancement of public services (Matheus *et al.*, 2020). In particular, data ecosystems streamline the timely acquisition of data, facilitating access to up-to-date information to guide decision-making processes (Oliveira and Lóscio, 2018).

Despite these advantages, significant challenges persist for educational data ecosystems to reach their full potential. One of the most pressing issues is the need for a more unified and comprehensive view of educational information. This would enable public managers to assess data from both historical and geographical perspectives, providing a richer context for analysis and decision-making (Ervina *et al.*, 2022; Luan *et al.*, 2020). Another major obstacle is the uneven distribution of resources at the municipal level. Many municipalities lack the necessary funding and infrastructure to adopt advanced technologies, leading to significant disparities in technological maturity across different regions (Przeybilovicz *et al.*, 2018). These disparities can result in inconsistent data quality and availability, which in turn affect the effective management of public education. The lack of updated and comprehensive information hampers the ability to monitor educational policies and constrains the decision-making processes of public managers. Without reliable data, it becomes difficult to implement evidence-based policies, allocate resources efficiently, and measure progress towards goals (Ervina *et al.*, 2022).

One strategy to reduce disparities in educational data ecosystems is orchestration. According to Autio (2010), orchestration involves aligning various actors within the ecosystem towards common goals, effectively coordinating resources and activities to achieve specific objectives. This process can be particularly beneficial in addressing the uneven distribution of technological resources and capabilities across municipalities. By having a central actor within the ecosystem, typically a higher-level governmental or educational institution, leading the orchestration efforts, it is possible to leverage their legitimacy and influence to guide and support necessary actions by other participants (Cui and Han, 2021). This central actor can play a crucial role in streamlining data management practices, ensuring that all municipalities adhere to standardized protocols and benefit from shared resources. Consequently, orchestration can enhance the overall efficiency and effectiveness of educational public management, providing managers with reliable insights for informed decision-making. Implementing such a coordinated approach helps mitigate the challenges posed by resource limitations and technological disparities, promoting a more equitable and cohesive educational data ecosystem (Chirico *et al.*, 2011; Autio, 2010).

In this context, data strategy also emerges as a concept relevant to addressing challenges in the data ecosystem. It involves a structured plan aimed at managing, safeguarding, and efficiently utilizing existing data, fostering the generation of knowledge and information, thereby enhancing decision-making processes (Gür *et al.*, 2021). By integrating the principles of data strategy and orchestration, it becomes apparent that their synergy can enhance the monitoring of public policies. Moreover, strategically consolidating data from various stakeholders offers a comprehensive view, simplifying its management. As a result, decision-makers can analyze trends, disparities, and areas for improvement across the education system. This, in turn, facilitates informed decision-making, targeted resource allocation, and more efficient data governance (Cordella and Paletti, 2019).

Thus, considering the recent technological advances that have enabled the development of an educational data ecosystem, as well as the importance of education as a collaborative public policy, and the relevance of the concepts of orchestration and data strategy, this research explores the opportunities arising from data orchestration within the educational data ecosystem. To achieve this, a case study was conducted on the Education Control Panel, a dashboard developed by the Audit Court of Espírito Santo (TCEES) that utilized elements of orchestration and data strategy in its construction. To investigate the opportunities arising from data orchestration in this case study, a cross-referencing with the literature is conducted, identifying processes of structuring, bundling, and leveraging proposed by the Resource Orchestration Theory (Cui and Han, 2021), with the latter representing opportunities for the improvement of public management. To complement the results, the dimensions of data strategy proposed by the literature (Gür *et al.*, 2021) are also analyzed in relation to the case study.

The results of this study are anticipated to significantly enhance the development of public policies by improving the management of education through public entities and highlighting the crucial role of data orchestration in monitoring these policies. Additionally, this research offers a practical example of using data orchestration in conjunction with data strategy, marking one of the pioneering efforts in this area. The following chapter explains the theoretical concepts of orchestration and data strategy, followed by a detailed explanation of the methodology used and an in-depth presentation of the case study. The study concludes with a discussion of the findings, limitations, and recommendations for future research, providing a comprehensive understanding of the subject.

2 ORCHESTRATION AND DATA STRATEGY

In ecosystems, orchestration plays a crucial role in fostering alignment among actors by promoting collaboration and establishing mutually beneficial relationships (Chirico *et al*., 2011). Sirmon *et al.* (2007) further support this perspective, emphasizing that success within ecosystems depends on understanding the ecosystem's context and its intricate interrelationships. The authors point that recognizing these dynamics allows participants to identify opportunities and weaknesses, enabling them to leverage their collective strengths and address challenges more effectively, enhancing the overall performance and sustainability of the ecosystem.

From a theoretical perspective, the Resource Orchestration Theory posits that orchestration involves structuring ecosystem resources, bundling them in an optimized and complementary manner, and leveraging them to create value for ecosystem actors (Cui and Han, 2021). These activities are often led by a central actor within the ecosystem, who aims to achieve superior outcomes compared to individual efforts. Consequently, effective orchestration directly contributes to the attainment of ecosystem objectives (Chirico *et al.*, 2011, Sirmon *et al.*, 2007).

Integrating diverse actors within an ecosystem is vital for enhancing operational efficiency, as the availability of reliable and up-to-date information significantly improves the quality of decision-making processes (Vafaei-Zadeh *et al.*, 2020). This principle is particularly pertinent when considering the broader context of ecosystems and the intersectionality of public policies. Guggenberger *et al.* (2020) argue that a unified effort towards data integration is essential for optimizing management activities across various sectors. Similarly, Luan *et al.* (2020) emphasize the importance of collaborative approaches in public policy management, highlighting that the intersection of different policy areas can lead to more effective outcomes. Concerning public education, this collaborative approach can significantly enhance the monitoring and implementation of educational policies by aligning efforts across different levels of government and leveraging shared data resources. This integrated strategy not only promotes transparency and accountability but also drives innovation and efficiency in educational management (Jatmiko *et al.*, 2022).

In this context, with the progression of digital technologies within governments (Viana, 2021), data emerges as a resource to be orchestrated within the ecosystem. One of the primary goals of this orchestration is to utilize data to facilitate decision-making, thereby enhancing the efficiency and effectiveness of public administration. As proposed by the Resource Orchestration Theory, having a strategy that outlines and communicates its objectives to stakeholders is fundamental (Cui and Han, 2021). Therefore, a concept gaining significance within the data orchestration perspective is data strategy.

In terms of the characteristics of data strategy, Gür *et al.* (2021) propose analyzing it through dimensions. For the scope of this research, the nine dimensions suggested by the authors were adjusted to fit the ecosystem context, resulting in five dimensions: strategic statement, data assets and sources, ecosystem alignment, strategy implementation, and purpose. Through these dimensions, the alignment between data strategy and orchestration is evident, as both focus on strategically consolidating resources (data) to achieve shared objectives. Thus, it is noted that the data strategy taxonomy proposed by Gür *et al.* (2021) is of interest for investigating opportunities in the educational data ecosystem, potentially contributing to the efficiency of education management and the improvement of decision-making by managers.

Hence, it is suggested that orchestration, encompassing the processes of structuring, bundling, and leveraging, may facilitate the dissemination and implementation of data strategy within ecosystems, as delineated by the dimensions of the strategic statement, data assets and sources, ecosystem alignment, strategy implementation, and purpose (Cui and Han, 2022; Gür *et al.*, 2021). To illustrate the practical application of these theoretical frameworks, the subsequent chapter indicates the methodology employed in conducting this case study.

3 METHODOLOGY

In terms of methodology, this study adopts a case study approach, characterized by an in-depth examination of the subject under investigation. A key advantage of employing a case study methodology is its ability to utilize diverse sources of information, thereby facilitating a comprehensive analysis of the subject from multiple perspectives (Yin, 2017). Specifically, this case study is categorized as descriptive, aiming to provide a detailed portrayal of the phenomenon within its contextual framework (Priya, 2021).

The subject of analysis is the Education Control Panel, a dashboard publicly accessible via the TCEES website at https://paineldecontrole.tcees.tc.br/, as shown in Figure 1. This study explores the dashboard's contents and examines how they intersect with the existing literature on orchestration and data strategy, particularly regarding their potential contributions to the advancement of data orchestration and the enhancement of public education policies.

Figure 1: Dashboard's initial screen.

Source: https://paineldecontrole.tcees.tc.br/

Particularly, the analysis focuses on the processes of structuring, bundling, and leveraging as detailed in the orchestration literature (Sirmon et al., 2011). Emphasis is placed on leveraging actions, which are crucial for advancing public policies. These actions offer strategic opportunities to effectively utilize information and knowledge, thereby enhancing the efficiency of public administration and supporting the monitoring and implementation of educational policies (Jatmiko *et al.*, 2022; Cui and Han, 2021). By examining these orchestration processes, this research aims to illustrate how strategic data management can lead to more informed decision-making and improved outcomes in public policy.

Additionally, intersections with the dimensions outlined in the data strategy literature (Gür *et al.*, 2021) are examined to improve the understanding of their association with orchestration, thereby providing a comprehensive perspective on the synergies between these concepts. The five dimensions under analysis are strategic statement, data assets and sources, ecosystem alignment, strategy implementation, and purpose. A review of technical documents and literature was conducted to clarify specific details regarding the dashboard. With a thorough understanding of the methodology, the subsequent chapter explores the case study in detail.

4 CASE STUDY

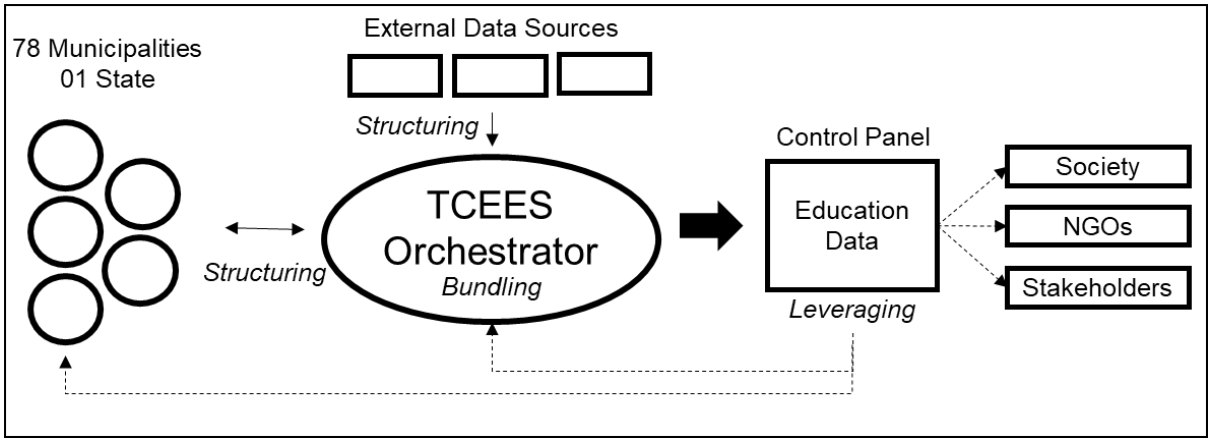
The Education Control Panel, established by the data orchestration efforts of the Audit Court of Espírito Santo (TCEES), functions as a centralized platform aggregating data from diverse sources to provide a comprehensive overview of the state's educational landscape. This dashboard enables both government officials and the public to effectively monitor relevant education metrics. In line with the standards set by TCEES, municipalities and other participants regularly submit data, which is combined with sources from various outlets, including the Educational Census, surveys by the National Institute for Educational Studies and Research Anísio Teixeira (Inep), and information from CidadES. CidadES, a system owned by TCEES, was initially designed to consolidate the accounting and budgetary records of municipalities in Espírito Santo to support TCEES's audit and control activities. However, it has since expanded to cover additional areas of public concern. Currently, parts of its dataset contribute to thematic dashboards, such as the Education Control Panel (TCEES, n.d.-a, n.d.-b).

Analyzing the Education Control Panel through the lens of orchestration literature (Chirico *et al.*, 2011; Sirmon *et al.*, 2007), it becomes clear that aligning data-related objectives required effective coordination between TCEES and municipalities. This alignment ensured the ecosystem pursued common goals, enhancing the efficiency of data management and policy implementation. The emphasis on transparency and accountability encouraged public officials to exceed mere compliance with legal obligations, fostering a culture of openness and responsibility. This configuration, as described by Guggenberger *et al.* (2020), exemplifies an orchestrated data ecosystem, with TCEES as the central institution.

In this central role, TCEES guides and coordinates the actions of other ecosystem actors, particularly municipalities. This centralization streamlines data management processes and facilitates the dissemination of data best practices and standards. The ecosystem displays the essential features of the 'orchestrated' typology, where a central organization leads towards a specific goal (Guggenberger *et al.*, 2020), making it suitable for analysis under the Resource Orchestration Theory (Cui and Han, 2022).

Technical documentation (TCEES, n.d.-a, n.d.-b) indicates that constructing the Education Control Panel required data from multiple sources, as depicted in Figure 2. This illustration provides a simplified view of the data ecosystem used for the dashboard, highlighting TCEES as the orchestrator and municipalities as orchestrated actors. Through collaboration with municipalities and external sources, TCEES conducted structuring activities and managed the bundling activities as the orchestrator. Leveraging activities are enabled through the dashboard, which presents strategically curated data, including historical and comparative perspectives. This accentuates the importance of data strategy in the dashboard's design, aiming to address education-related issues in municipalities.

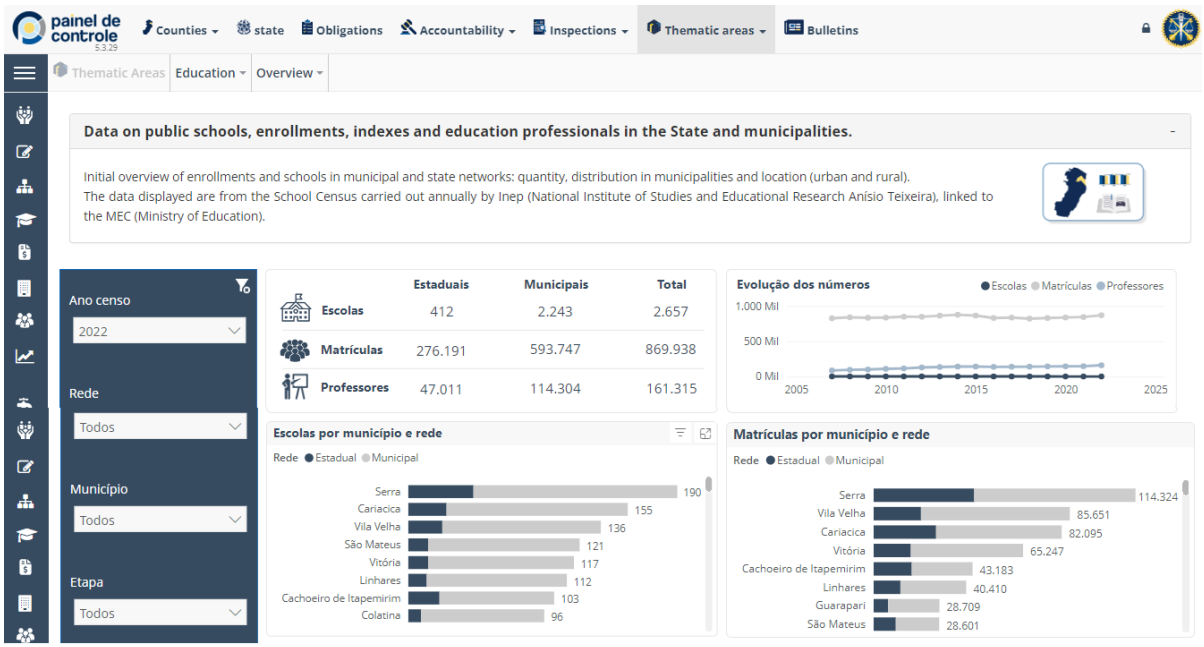
Figure 2: Representation of orchestration activities in the data ecosystem.



Also, the Education Control Panel offers data in an open format, delivering relevant benefits such as increased social oversight by citizens and improved support for public managers in making informed decisions (Hagen *et al.*, 2019). This active transparency cultivates a data-driven culture among ecosystem stakeholders, where robust data governance clearly defines roles and responsibilities in the development of the Education Control Panel, all under the orchestration of TCEES (Salerno and Maçada, 2022).

To illustrate, the Education Control Panel's overview is shown in Figure 3. Its structure comprises eight menus: *Overview, Schools, Basic Education Development Index (Ideb), School Dropout Rate, Basic Education Evaluation Program, Fluency Test, Professionals, and Inactives*. Each menu will be detailed in sequence, emphasizing how the data can contribute to public policy development through opportunities derived from orchestration, particularly leveraging activities.

Figure 3: Education Control Panel's overview.



Source: https://paineldecontrole.tcees.tc.br/areasTematicas/Educacao-VisaoGeral

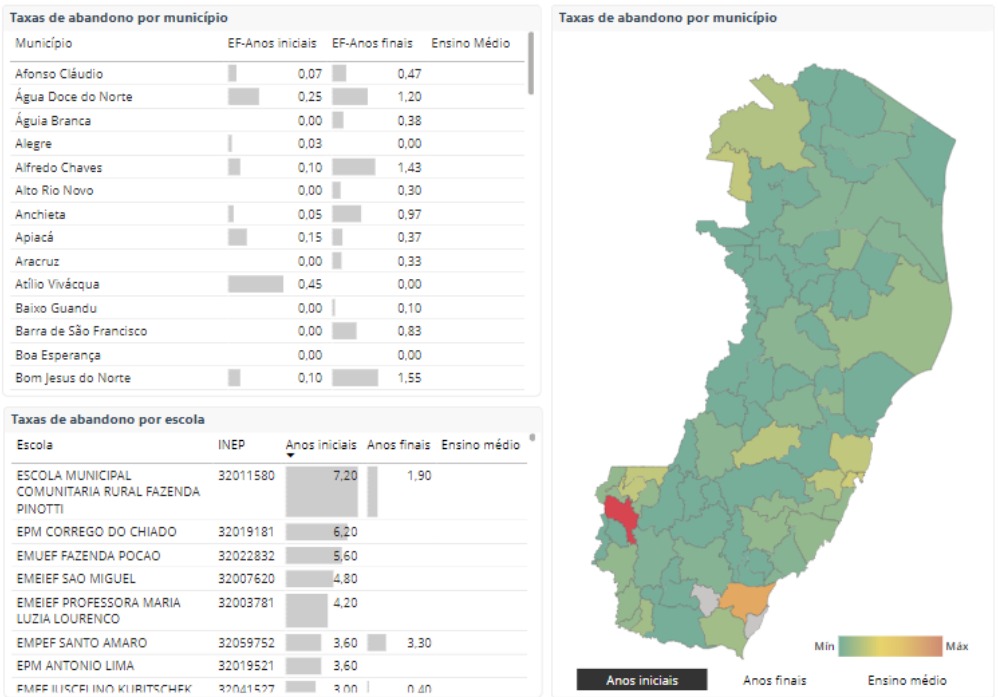
The *Overview* menu of the Education Dashboard demonstrates data about schools, enrollments, and teachers in municipalities in Espírito Santo, providing detailed information about both the state and municipal networks. This visualization, particularly from a geographical perspective, is useful for analyzing regional inequalities (Hagen *et al.*, 2019), such as the concentration of schools in the metropolitan region of Vitória and coastal municipalities. This perspective aids public officials in identifying improvement opportunities at both the local and regional levels to ensure that the population has access to education across various regions of the state.

The *Schools* menu offers comprehensive data on enrollment numbers per school, network, and location (rural/urban). Beyond simply visualizing schools within the municipality, the dashboard furnishes information regarding the student-to-teacher ratio. Consequently, it enables public officials to gauge class sizes, essential for assessing requirements concerning physical infrastructure and staffing (Zwick, 2012).

The *Basic Education Development Index (Ideb)* menu presents data on this indicator for municipalities in Espírito Santo. Ideb was created by the federal government to measure the quality of education in public schools, resulting from the performance averages in the assessment of the Basic Education Assessment System (Saeb) and school flow (Inep, 2024). The dashboard assists public officials in pinpointing potential educational weaknesses across different stages, as it provides data on early years, final years, and high school education.

The *School Dropout Rate* menu displays the percentage of students enrolled in each educational stage who discontinued attending school throughout the academic year, as shown in Figure 4. This breakdown of data by school enables public officials to identify issues and make informed decisions as School dropout rates are among the significant challenges in education underscoring the importance of aggregating data from various sources (bundling) (Ervina *et al.*, 2022; Luan *et al.*, 2020).

Figure 4: School dropout rates visualization.



Source: https://paineldecontrole.tcees.tc.br/areasTematicas/Educacao-Abandono

The *Basic Education Assessment Program (Paebes)* menu presents data from the education assessment conducted by the State, aiming to evaluate the quality of basic education in the state public network and, by adherence, municipal and private networks (Espírito Santo, 2024). This visualization enables public officials to compare the performance of public schools with private ones, which is crucial for reducing inequalities between public and private education (Ervina *et al.*, 2022; Luan *et al.*, 2020).

Through the *Fluency Test* menu, data are available to identify the level of reading fluency among students. Once again, it is evident that the dashboard addresses an important challenge in education, indicating significant weaknesses in students' reading fluency (Morales and Barros, 2023). Cross-referencing with other data facilitated by bundling actions enables an investigation into whether the results are influenced by factors such as the number of teachers and the school's location. This approach allows public officials and society to analyze the problem from multiple perspectives.

Finally, the *Professionals and Inactives* tabs offer data on teachers, including information such as salaries, qualifications, age ranges, and demographics. These data are crucial for identifying the professional workforce, assisting in the planning of new hires, and providing insights into teacher retirements and qualifications (Zwick, 2012). Hence, these data are instrumental in delineating the educational workforce, facilitating strategic personnel planning, and providing valuable insights into educator retirements and qualifications.

Having comprehended the primary information presented in the Education Control Panel, the next step is to identify orchestration activities and leveraging opportunities (Table 1), and also delineate the characteristics of the data strategy (Table 2). Orchestration processes and data strategy dimensions were drawn from the literature, aiming to contextualize theoretical concepts within empirical activities and identify opportunities arising from data orchestration (Gür *et al.*, 2021; Guggenberger *et al.*, 2020; Cui and Han, 2022).

As outlined in the Resource Orchestration Theory (Cui and Han, 2022), leveraging actions related to data strategy provide municipalities with significant opportunities to derive value from data. As shown in Table 1 and Table 2, the orchestration by TCEES has enhanced the 'purpose' dimension of the data strategy by consolidating data through structuring and bundling processes, integral to the 'data assets and sources' dimension. This has allowed municipalities to better utilize their data resources for informed decision-making and policy implementation. Additionally, the 'Strategy Implementation' dimension details how data are disseminated via the Education Control Panel, ensuring that all stakeholders have access to necessary information. Effective data dissemination maintains transparency and accountability, fostering a culture of data-driven decision-making. The 'Ecosystem Alignment' dimension, led by TCEES, integrates diverse stakeholders, promoting collaboration and efficient sharing of resources and knowledge. This cohesive environment enhances the data ecosystem and encourages data-driven innovations (Gür et al., 2021).

Thus, the orchestration efforts by TCEES exemplify how a well-structured and implemented data strategy can improve educational data management and policy-making, highlighting the potential for data orchestration to transform public administration and achieve educational goals.

Hence, the opportunities arising from data orchestration within the educational data ecosystem, as identified in this case study, are reflected in the leveraging dimension of the Resource Orchestration Theory, as shown in Table 1. These opportunities represent ways to harness and capitalize on the informational assets provided by the Education Control Panel. The identified prospects include utilizing data to support municipal education planning, strategically using information by public officials, addressing complex education issues such as school dropout rates and lack of reading fluency, and enhancing public management. These opportunities align with the data strategy, as leveraging initiatives are supported by a clearly defined and collectively embraced data strategy within the ecosystem, aimed at improving public services (Table 2).

Table 1: Summary of orchestration processes and activities

Orchestration Processes (Cui and Han, 2022)	**Identified Activities**
Structuring	• Data collection and storage from partners. • Information system (CidadES) integrated with partners. • Specific unit responsible for data structuring.
Bundling	• Aggregating data from different sources. • Integrating internal and external data to aid decision-making. • Enhancing control and audit activities through data cross-referencing.
Leveraging	• Using data to monitor public education policies. • Supporting municipal education planning. • Strategic use of information by public officials. • Using data to address complex education issues, such as school dropout rates and lack of reading fluency.

Table 2: Summary of data strategy characteristics

Data Strategy Dimension (Gür *et al.*, 2021)	**Identified Characteristics**
Declaration of Strategy	• Incorporated into official documents. • Aligned with national education objectives. • Regularly updated to reflect policy changes and technological advancements.

Data Strategy Dimension (Gür *et al.*, 2021)	**Identified Characteristics**
Data Assets and Sources	• Defined in the dashboard tool. • External and internal. • Utilizes historical data for trend analysis.
Ecosystem Alignment	• Technological infrastructure in own system. • Designated data responsible staff in each municipality. • Mobilization of resources by the orchestrator. • Communication through explanatory notes and informative materials. • Continuous training programs for municipal staff.
Strategy Implementation	• Business Intelligence. • Menu planning. • User-friendly interface with interactive data visualizations.
Purpose	• Enhancement of public management. • Audit and control. • Monitoring and evaluation of public policies. • Increase transparency and accountability to the public. • Facilitate targeted interventions and resource allocation.

Having identified the intersections with the literature on orchestration and data strategy, as well as the opportunities arising from these concepts in the present case study, the next chapter presents the conclusions obtained, as well as the limitations of this research and suggestions for future research.

5 CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

This research explored the opportunities arising from the data orchestration in the educational data ecosystem. To do so, a case study of the Education Control Panel from TCEES was conducted, analyzing the processes of structuring, bundling, and leveraging, as indicated by the Resource Orchestration Theory (Cui and Han, 2022). Additionally, the dimensions of the data strategy were analyzed by adapting the taxonomy proposed by Gür et al. (2021) to the ecosystem context.

The case study revealed that the dashboard offers insights enabling municipalities to enhance their educational management, with orchestration facilitating leveraging actions that support planning and decision-making by managers. Noteworthy leveraging opportunities encompass utilizing data to monitor public education policies, enhancing municipal education planning, promoting strategic information usage by public officials, and tackling complex education challenges. These findings emphasize the applicability of Resource Orchestration Theory in understanding how strategic data management can optimize educational outcomes and drive improvements in public management.

Furthermore, the findings provided insights into the data strategy employed in developing the Education Control Panel. By examining the dimensions of the data strategy defined in the literature (Gür et al., 2021) and comparing them with the observed characteristics in this case study, a deeper understanding of public data practices is gained. This comparison yields valuable insights into the practical application of data strategy and its interaction with orchestration activities. Notably, within the "Ecosystem Alignment" dimension, TCEES assumes a pivotal role by overseeing technological infrastructure, resource mobilization, and communication with municipalities and stakeholders. This practical application exemplifies the concept of an orchestrated data ecosystem as defined by Guggenberger et al. (2020).

In addition, the research highlights the significance of TCEES's role in orchestrating the data ecosystem, ensuring that the data resources are effectively mobilized to support educational management across municipalities. The practical insights gained from this case study demonstrate that a well-orchestrated data ecosystem not only facilitates the efficient management of educational data but also empowers municipalities to make informed decisions, thereby enhancing the overall quality of public education and addressing its critical problems (Ervina et al., 2022; Luan et al., 2020). In the context of public policy, this research furnishes evidence that aids researchers and managers in comprehending the role of data orchestration in enhancing public services, notably as a mechanism for leveraging data-driven initiatives. It is anticipated that this research will stimulate research on orchestration and data strategy within the public sector, further advancing the Resource Orchestration Theory.

One of the limitations of this study is the limited investigation of the technological tools utilized by municipalities, with the focus primarily on the perspective of the orchestrator (TCEES). Future research could explore assessing the efficacy of leveraging actions in municipalities, thereby identifying the benefits accrued for society and public management.

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