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Application of Business Intelligence in the Brazilian Educational System

Aplicação de Business Intelligence no Sistema Educacional Brasileiro

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Abstract
In this article, we will discuss an application of Business Intelligence (BI) in analyzing data from the Brazilian educational system, specifically working with INEP (The Instituto Brasileiro de Geografia e Estatística — IBGE). This paper then discusses BI implementation's positive contributions and critical challenges in this domain. From the construction of an integrated BI system, our study aimed to offer a helpful tool that was easy to handle and touched on visuals such as dashboards, tables, and graphs to help us understand and manage the educational scenery throughout Brazil. The methodology used has been applied, with case studies and bibliographical research, based on data analysis techniques such as ETL (Extract, Transform, Load) and Data Warehousing. This is all leveraged to interactive dashboards, which should enable data-driven decisions and forge the way for advanced analytics like data mining.
Keywords: Business Intelligence. Brazilian Educational System. Data Warehousing. INEP. ETL Process. Educational Data Analysis. Decision-Making in Education. Educational Dashboards. IDEB. Educational Policy.

Resumo
Neste artigo, discutiremos uma aplicação de Business Intelligence (BI) na análise de dados do sistema educacional brasileiro, trabalhando especificamente com o INEP (Instituto Brasileiro de Geografia e Estatística — IBGE). Este artigo discute as contribuições positivas e os desafios críticos da implementação de BI neste domínio. A partir da construção de um sistema de BI integrado, nosso estudo teve como objetivo oferecer uma ferramenta útil, fácil de manusear e que abordasse recursos visuais como dashboards, tabelas e gráficos para nos ajudar a entender e gerenciar o cenário educacional em todo o Brasil. A metodologia utilizada foi aplicada, com estudos de caso e pesquisa bibliográfica, com base em técnicas de análise de dados como ETL (Extract, Transform, Load) e

Data Warehousing. Tudo isso é alavancado para dashboards interativos, que devem permitir decisões baseadas em dados e abrir caminho para análises avançadas como mineração de dados.
Palavras-chave: Business Intelligence. Sistema Educacional Brasileiro. Data Warehousing. INEP. Processo ETL. Análise de Dados Educacionais. Tomada de Decisão em Educação. Painéis Educacionais. IDEB. Política Educacional.

1. Introduction

Thanks to the significant demand for high-quality education, the education sector and policy makers were forced to look for ways to enhance the management and analysis of educational systems. To assess the impact of the educational system in Brazil, there is a need not just for data availability but also for the development of effective use of data. This effective use of data is crucial as it enables proper decision making. One of the most effective and efficient methods of visually representing large amounts of educational information is the use of Business Intelligence (BI).

Key indicators of the Brazilian educational system are overseen by numerous indices that include the Basic Education Development Index (**IDEB;** from Portuguese, Índice de Desenvolvimento da Educação Básica), Course Concept (**CC**; From Portuguese, Conceito de Curso), Preliminary Course Concept (**CPC**; from Portuguese, Conceito Preliminar de Curso), among other relevant indices, which has been able to keep large visualization and data analytic tools. Despite these advancements, the ability to obtain and process such data in a readable and understandable way is a major issue for teachers, educational managers and society in general. This study attempts to tackle this pressing problem by suggesting the introduction of a BI system within the appropriate context of the Brazilian education system.

This article aims at designing interfaces of BI which will ease the access to education data to the stakeholders. This not only allows for proper decision-making but also paves the way for the exciting potential of advanced analytics in the Brazilian education system.

The paper is organized in the following way. The first section provides a comprehensive overview of the existing literature relating to Business Intelligence and its use in educational settings. This thorough review forms the solid foundation for the subsequent sections. The next section concerns the methodology and describes the research design as well as the data analysis techniques employed. Subsequently, the application of BI in education in Brazil is analyzed, and finally, the main conclusions and contributions of the research report are presented.

2. Literature Review

The literature review explores the two main themes of this study: the structure of the Brazilian educational system and the application of Business Intelligence (BI) to improve educational data analysis. Both topics are discussed in depth, emphasizing how BI can support data-driven decisions in the educational sector.

2.1 Brazilian Educational System

The Brazilian educational system is composed of basic education (early childhood, elementary, and high school) and higher education. Historically, education in Brazil has evolved significantly, moving from the Jesuit influence during the colonial period to a state-regulated system based on constitutional rights (Ribeiro, 1993; Vieira & Albuquerque, 2001). The National Education Guidelines and Bases Law (**LDB;** from Portuguese, Lei de Diretrizes e Bases da Educação Nacional), of 1996 established a formal structure for education, ensuring the right to quality education for all citizens. This legislation was a key milestone in organizing the system into basic and higher education and assigning specific roles to federal, state, and municipal governments (Education, 1996).

To monitor the quality of education, the Brazilian government has introduced several **key performance indicators**, such as the **IDEB**, the **CPC**, and the General Course Index (IGC, from Portuguese, Índice Geral de Cursos) (Pontes, 2012). These metrics provide valuable insights into

the performance of schools and higher education institutions. However, making sense of these complex data sets poses challenges for educators and policymakers.

Evaluation systems such as National Basic Education Assessment System (**SAEB**, from Portuguese, Sistema Nacional de Avaliação da Educação Básica), **Brazil Exam**, National High School Examination (**Enem**, from Portuguese, Exame Nacional do Ensino Médio) and National Student Performance Exam (**ENADE,** from Portuguese, Exame Nacional de Desempenho de Estudantes) generate a wealth of data, but these are often fragmented across various platforms, making it difficult to create a comprehensive overview of the educational system (Soares & Colares, 2020). In this context, integrating BI tools into the educational system could provide a clearer picture by consolidating data from multiple sources and presenting it in an easily interpretable manner (Fontanive, 2009).

2.2 Business Intelligence (BI)

Business Intelligence (BI) is a set of strategies, technologies, and processes used to collect, analyze, and present business data to facilitate decision-making. BI tools allow for the extraction and transformation of raw data into actionable insights, providing organizations with the means to make data-driven decisions (Inmon, 2005). Luhn (1958) was one of the first to define BI as a system for processing information to support decision-making processes. Over time, the concept evolved, with modern BI systems now incorporating tools for data warehousing, ETL processes (Extract, Transform, Load), and data mining (Chaudhuri *et al*., 2011).

The relevance of BI in various sectors, including education, has grown significantly. BI systems are designed to support the collection and processing of large datasets, enabling decision-makers to access comprehensive, multi-dimensional analyses (Turban *et al*., 2009). Popovic *et al*. (2012) explain that BI systems can offer detailed insights into past and current trends, enabling *organizations* to predict future scenarios and make informed decisions. In education, this capacity for in-depth analysis is particularly useful for identifying performance patterns and areas that require improvement.

2.3 Application of BI in Education

Several studies have examined the use of BI in educational contexts. Breiter, A., & Light, D. (2006) highlighted the potential of BI to support decision-making in schools by providing clear and organized reports of student performance. BI tools also allow educators and administrators to monitor key performance indicators and track progress over time. As Habul & Pilav-Velic (2010) point out, BI systems can improve strategic planning in educational institutions by offering a comprehensive view of institutional data.

In Brazil, INEP collects a wide range of educational data, including student assessments and institutional evaluations (Santos *et al*., 2020). However, the challenge lies in processing this data in a way that makes it accessible to users. BI offers a solution to this problem by centralizing data and presenting it in the form of dashboards, charts, and interactive tables (Rothen & Santana, 2018). For example, Chaudhuri and Dayal (1997) emphasized that BI architectures typically rely on multi-source data integration, such as combining INEP data with additional institutional sources, to create a holistic view of the educational landscape.

The Data Warehousing approach in BI allows for the storage and management of large volumes of educational data, providing a single, unified view of information. This is particularly important in educational systems where data may come from various levels (national, state, and municipal) and across different educational stages (basic education, higher education). By employing BI, educational authorities can better understand the system's performance and make informed decisions to address areas in need of improvement (Silva, 2006).

2.4 Related Works

The application of BI in education is still evolving, but it is gaining traction as a valuable tool for improving decision-making processes. Turban *et al*. (2009) noted that the integration of BI into education allows institutions to move from reactive to proactive decision-making by providing real-time data and predictions. Similarly, **Porto and Régnier (2003)** argue that access to reliable educational data is critical for improving teaching quality and ensuring the efficient allocation of resources.

The increasing importance of data-driven decision-making in education underscores the need for tools like BI. By integrating BI into the management of the Brazilian educational system, this research aims to create more accessible and actionable insights, helping policymakers and educators better navigate the complexities of education in Brazil.

3. Methodology

The research conducted in this study follows an applied nature, combining **exploratory** and **descriptive** objectives, with a quantitative approach. The goal is to develop and evaluate the application of a **Business Intelligence (BI)** system in the Brazilian educational context using data provided by **INEP**. The following steps outline the research methodology used:

3.1 Research Strategy

The study strategically adopted a **case study** strategy, focusing on the Brazilian educational system as a practical scenario. By using real-world data from INEP, this case study provided a deep analysis of the challenges and contributions of using BI tools to enhance decision-making processes in education, demonstrating its real-world applicability.

3.2 Data Collection

Data collection relied on public databases made available by INEP in the sequence as presented in Figure 1. These databases contain a comprehensive range of educational data, including student performance, institutional evaluations, and key educational metrics like **IDEB**, **ENADE**, and **CPC**. The data spans different educational levels, such as **basic education** and **higher education**, enabling a thorough analysis of the system.

The data was extracted using **ETL (Extract, Transform, Load)** processes, a systematic approach that involved the following steps:

Extraction of data from INEP's raw datasets;

Transformation, which cleaned and standardized the data for analysis, ensuring it was compatible with the BI system;

Loading the transformed data into the **Data Warehouse**, making it available for querying and analysis through BI tools.
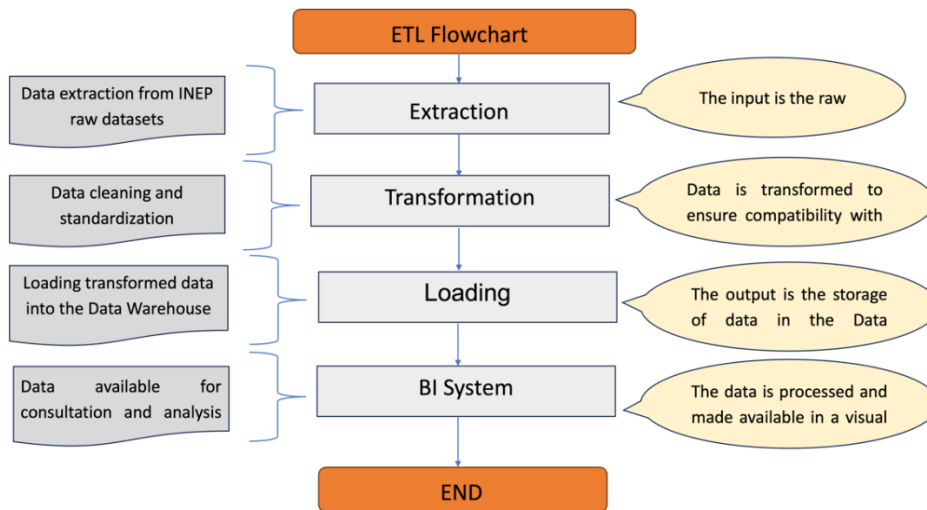
Figure 1 – Flowchart of Collect Data.

3.3 Data Analysis Techniques

All the data was analyzed using Data Warehouse and Business Intelligence tools. This analysis involved:

- The using dimensional modeling through star schema structures for the data warehouse that would let data be well sorted and queried within the educational context at the university.
- Dashboard creation entailed outlining the user interface and data visualization framework that enables the end user to navigate deeper into the data to get insights from the data.
- For illustration purposes, tools such as charts, tables, and graphs were applied, and these can produce dynamic output that may otherwise make it hard to distinguish the relationship between various factors in the dataset.

3.4 Case Study**:** Adoption of BI in Brazil's Education System.

The above plan of using the BI system was put to the test through a specific case study. This study meant using a subset of educational data in Brazil regarding basic and higher education performance:

- Data was collected from different sources and compiled and analyzed to form a single database.
- Dashboards were developed to track and display KPIs, including IDEB, students' engagement with assessments, and performance of HEIs.
- The relevance of the BI system was tested by its effectiveness for decision-making for educational managers and policymakers.

3.5 Evaluation of Results

In essence, the impact of the BI system on the organization was determined from the accuracy, interactivity, and usability of the output displayed on the homepage and the dashboards as well as the management reports. Educational professionals and policymakers were interviewed to determine whether the BI system enhanced available educational data and decision-making. The approach used in this study was possible to map the BI applied in the context of the Brazilian educational system, which could support the enhancement of the method of management and reading of the results referred to educational performance.

4. Results

The application of the Business Intelligence (BI) system in the context of Brazilian education has revealed substantial and profound findings, primarily in data representation, business analytics, and the accessibility of educational information. The results are presented in three key areas: dashboard designing, data disaggregation, and ease of information system.

4.1 Dashboard Designing

The implementation of the BI system was effective in creating engaging and interactive decision-support dashboards that comprehensively cover all aspects of education, allowing users to analyze data related to school performance, institutional quality, and student accomplishment. The dashboards were intended to report educational indices such as IEDB, students' engagement in tests, and enterprise assessments (INEP). For instance, they had dynamic graphs that could show student performance over a certain period, with region, municipality, and school indicators for primary education. Users could go from the general national-level data to individual schools, so it made it easier to analyze trends in performance. This is another functionality of BI tools that allows decision-makers to focus on areas of concern precisely (Turban *et al.*, 2009). Moreover, the higher education dashboard enabled consumers to analyze the performance of universities and colleges in Brazil. Values like CPC and IGC were given as figures and graphs to enable users to differentiate institutions and seek improvement or extra funding.

From the data obtained by the Dashboard, it was possible to generate a table with a summary of the national average, separating the data by capital or interior, rural or urban, state, federal or municipal, and the school year index with the corresponding subject. In this way, Figure 2 was constructed, showing the participation of students in the 5th year and 9th years of Elementary School (ES), High School (HS), Integrated High School (IHS), and Traditional High School (THS), and verify participation in the SAEB.
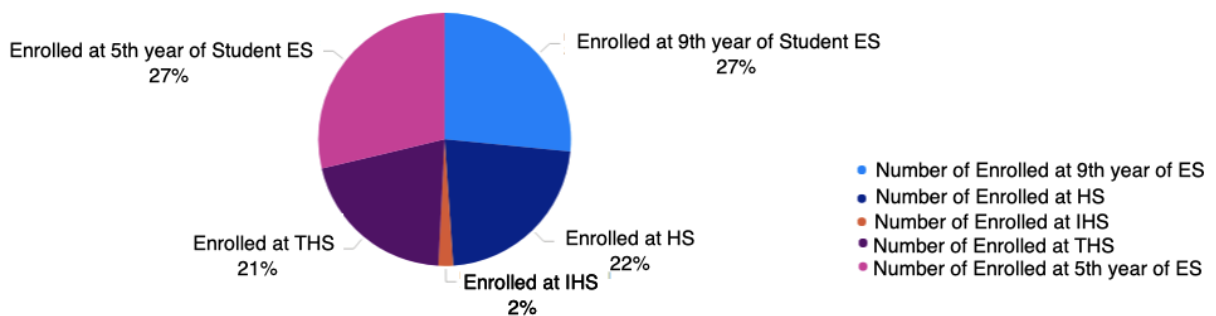

Figure 2 - Student distribution in 2019.

Figure 2 shows the distribution of students enrolled in the years that will be evaluated in this research.

Also, this Dashboard makes available a table that shows the relationship between the administrative category (public, private, special) and the region, showing the number of institutions in each region, their categories, and finally, the total number of institutions according to the filter, if any.

Figure 3 shows the IDEB score in 2019, along with its projection for 2019 at each stage of education (initial years, IY, final years, FY, and high school, HS) and in each education network (state, municipal, private). In Brazil, institutional responsibility for primary education is municipal, and responsibility for secondary schools is statewide.
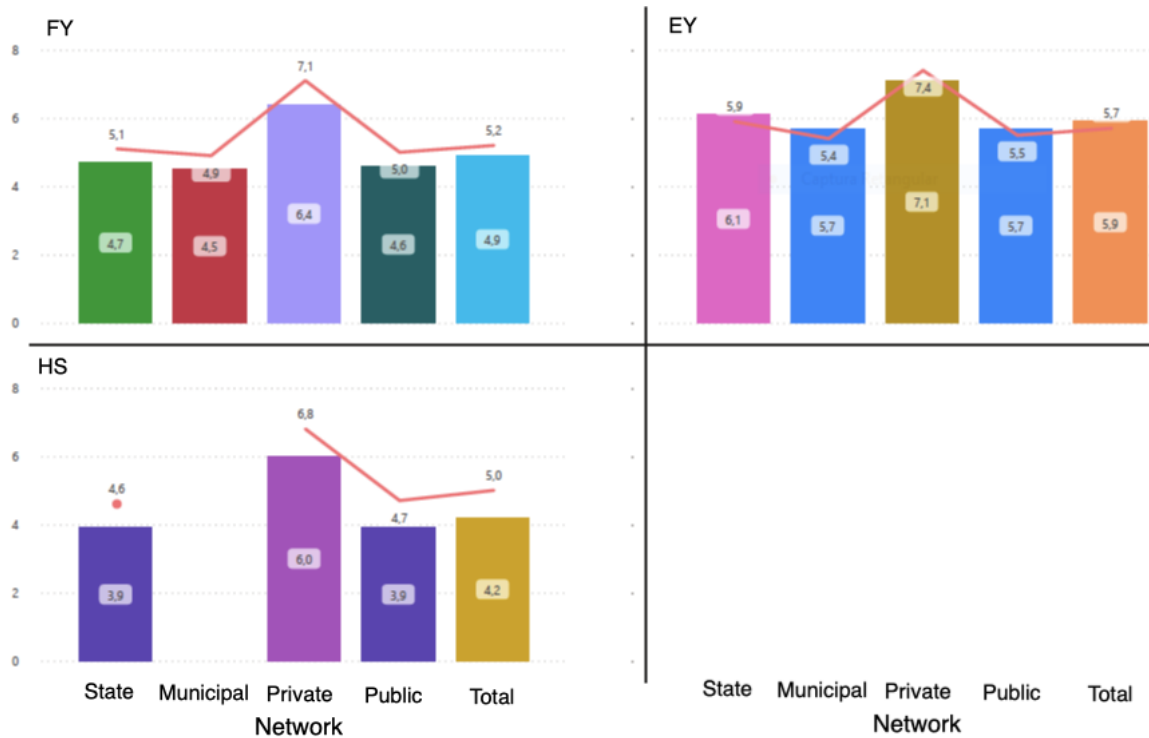
Figure 3 - (IDEB 2019 and Projections 2019) x Teaching Stage.

As can be seen in Figure 3, data are presented for both IDEB and projections, which facilitates decision-makers' analysis.

4.2 Data Disaggregation

When the data was analyzed using the BI system, it was possible to capture significant trends and patterns concerning Brazilian education. Students' performance in the examination and regional educational differences were among the most significant findings. For instance, data presented in the heading highlighted that North and Northeast Brazil have relatively lower IDEB than schools in South and Southeast regions (Moniz Jr., 2021). Moreover, the BI system's unique capability to capture data from various educational stages, such as basic and higher education, allowed us to establish insightful links. This integration established connections between learning in primary education and results in higher education, for example, the rate of students entering universities, their progress, and pass rate in national exams at the end of their first year, ENADE. It also made it easier to determine the behavior of education policies by comparing data prior to and after policy changes. For example, using the results of SAEB and Brasil Exam tests, the impact of educational reforms was assessed since changes in results were observed before and after these reforms. In line with Rothen and Santana (2018), concern has been highlighted on how BI can facilitate evaluating public policy outcomes on education.

4.3 Information System

Respondents, including educational administrators and policymakers who are users of the present work, were encouraging. It was accepted that relying on colors makes dashboards complicated, and users appreciated how they could maneuver through the interfaces to get consolidated data about schools, institutions, and students within a single click of a button. For this reason, the system can convert the analyzed data into an easily understandable and more workable graphical form. Specifically, users identified the benefit of creating more reports and utilizing graphs, which are often accomplished to determine trends over time. For example, administrators

can quickly identify enrollment patterns and student and organizational performance, developing sound strategies and effective policies to enhance the institution. This position has supported the assertion made by Popovic *et al*. (2012) that BI systems provide utilitarian information that improves organizational decision-making (Moniz Jr., 2021).

Moreover, it can provide accurate and up-to-date data in the dashboards to the managers and the professionals from the raw sources through ETL processes. Such a feature allows one to expatriate the most updated data possible. Such an aspect is crucial in an ever-evolving sector such as education (Moniz Jr., 2021).

4.4 Challenges and Limitations

Despite this, the implementation of the system faced some problems during the implementation phase. One of the most significant challenges was data aggregation, specifically when working with outdated databases that the modern solutions in the field of BI can hardly support. The ETL processes needed more time and resources to perform proper data cleaning and transform all the data into a format suitable for analysis (Chaudhuri *et al*., 2011). Users also identified other limitations with BI tools, including the time taken to learn how the tool works. The system was proposed to be easily navigable by the user. However, the educational professionals needed to be trained to comprehend how to utilize all the features of the created dashboards and reports. This procedure highlights the need for constant training for organizations as BI systems become more institutionalized in educational management procedures.

5. Conclusions

This paper will discuss the principles of business intelligence put into practice in the Brazilian educational system, considering the possibility of interpreting and visualizing the results obtained from INEP and other educational databases. Thus, the study findings confirmed that BI is an effective method for enhancing the availability of educational data and its use in decision-making processes and structuring trends based on which public policy and resource provision can be devised. A significant novelty of this work was creating interactive dashboards that enabled users to visualize and analyze different and often intricate educational data. These dashboards helped to understand the differences between regions, strengthen institutional analysis, and evaluate student accomplishments, leading to better decisions from educational administrators. The combination of primary and higher education data also enabled one to examine the whole (educational system) picture. Under the challenges category, some of the problems identified were related to merging heterogeneous data sources and data reliability through the ETL process. However, as with any BI system, the training and technical support required to ensure users did not get "lost in the weeds" was evident.

For this reason, further support as BI tools gain adoption across educational institutions is a must-implement tenet. In general, using BI in education expands new opportunities for management decisions based on information. In this way, the BI systems can supply a vision to the educational administrative management of the country, contributing to the functional scope and improved guidance of the public policies, enhancing the quality of education in Brazil. New research could go further into the application of this study by applying superior data mining to improve education's data analysis.

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