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Chapter 8: Developing comprehensive data architectures for educational institutions to ensure consistency, accuracy, and accessibility across platforms

8.1 Introduction

As many educational institutions are entrusted with the primary responsibility to provide suitable training that would equip learners with the necessary talents and capabilities, they have a vital role in the development, management, delivery, and evaluation of the curricula for their services. Data is very important. By preserving, aggregating, and analyzing significant data, the institutions could capture the different dimensions of the curricula, model the various processes involved, and properly protect the collective wealth of the relevant information. Through this, they would be in a better position to provide quality services, comprehend the needs of the different partners in the education value chain, demonstrate their achievements, and follow up carefully on the different performances related to the business, managerial, and instructional operations. By making use of the qualities of the inherent IT technology, educational institutions, particularly those that operate within the context of e-education, including training centers, coursework providing entities, electronic tutoring services, and libraries, are able to exploit the different benefits of the web to provide electronic versions of their courses, create electronic knowledge representations with the expectation of being useful for those seeking certification, and address and satisfy both learners and trainers alike. With these models, they should be in a critical position to enable both the students and the teachers that are interacting within measurable and consistent institutional frameworks. With the passing of time, the different educational activities have become primarily performance or information exchange based. The increased level of competitiveness in the different education sectors increases this trend.

8.1.1. Understanding the Role of Data Architecture in Educational Settings

Educational institutions are persistently combating the level of quality education received by their students. Student-related data, also known as learner data, is one of the most crucial assets in terms of information that educational institutions process. The government's increasing effort to attain world-class education has prompted educational institutions to enhance their use of data and their data management. However, the educational context has a scarcity of literature regarding data management. In information systems literature, studies related to data management and data architecture are not widely covered in an educational setting; few publications have been made on the topic in the educational setting domain.

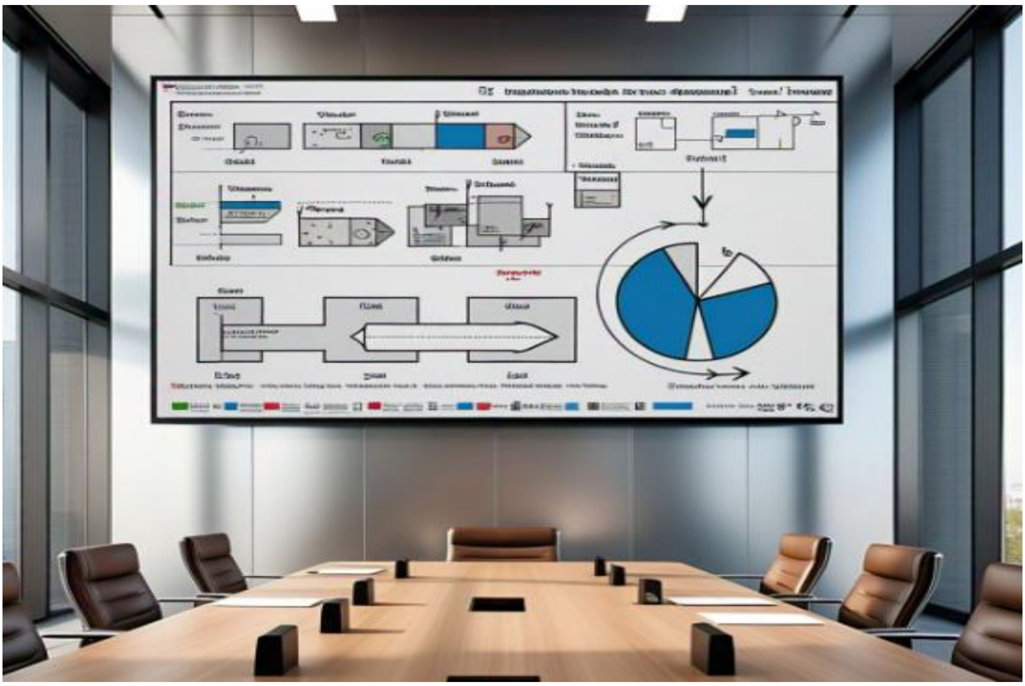

Fig 8.1 : Data Architecture

Today, higher education institutions are encountering a continuous flow of data from diverse sources such as students, alumni, parents, donors, educators, researchers, administrative staff, support staff, and professional organizations. These constituents operate in a complex institutional ecosystem with shifting sets of priorities governed by external compliance and accountability constraints from governmental bodies and accrediting agencies. In order to satisfy the needs of their constituents, the rapidly shifting global environment in which they operate, and the fundamental demand for accountability, higher education institutions have been urged to organize educational environments driven by learning goals and innovative pedagogy. However, many colleges and universities lag in their capability to use institutional information effectively in support of an institution's vision. Even institutions that are considered leaders in innovation, infrastructure, and repeated successes are unsure of the action items that they should recognize and enlist.

8.2. The Importance of Data Architecture in Education

In the last 20 years, many educational institutions have implemented different software solutions to enhance their business and teaching/learning processes. One of the most important by-products of the installation of software solutions in any organization is the generation of data. This data, if not correctly handled and put to good use, is a waste of the valuable resources expended to generate and collect it. In this sense, an architectural approach to data is a good starting point to establish standards to handle the hidden potential of educational data in universities and the collegiate product assured. Data architecture in education has specific characteristics that distinguish it from the corporate case, which is mainly overcoming hurdles to achieve the institutional education goal—its students' success.

However, data architecture is not commonly used in the academic context although it is crucial to the effective management of all the information used in a university. Information architecture and systems have been primarily studied in the context of business organizations, and this lack of attention to data architecture in the field of education has had a significant consequence. The IT areas inside educational institutions have produced value-added systems specializing in delivering inputs required for the institutional products. Furthermore, this is evident in the network of population universities serve, which is not easy to understand, let alone manage. This paper describes how data architecture can become a common tool for educational institutions, promoting integrated services and better information delivery on their main products: students.

8.2.1. Strategies for Effective Data Management in Education

The role of information and communication technologies in the education of the digital age is essential, as they can improve the learning and teaching process, enhance the management and administration of the educational system, and facilitate relations between all actors involved in the educational process. However, the creation and management of educational processes generates large amounts of data that, if not managed correctly, can become a source of problems for the educational institution. In order to successfully manage data and provide accurate and timely information to the users, it is necessary for educational institutions to develop a data architecture. In this sense, this paper explores the pertinent literature on the creation of data and information architectures and provides comprehensive strategies to develop data architectures in educational institutions. The process of designing a data architecture starts with thinking about the data required to support business operations. A comprehensive data model encompasses data from personnel, students, academics, and finance. The data required for administrative processes include catalog data, curriculum structure, class schedules, registration, fees, grades, and transcripts. Educational support processes capture the necessary requirements for managing office hours, grade entry, degree audits, financial aid and awards, teaching loads, and research activity. Student life or extracurricular activities include information processes for managing the activity hours of student unions, associations, clubs, or organizations. Handling data in the most efficient manner for large, complex, and distributed information systems can be achieved by categorizing data so that the approaches to management are well defined and communicated.

8.3. Current Challenges in Educational Data Management

Over the last decade, educational institutions have made enormous investments in administrative automation, including the acquisition and implementation of enterprise-wide administrative systems. Although educators have long recognized the importance of information for effective planning and decision-making, traditional stand-alone and non-integrated information systems created bespoke views of institutional performance and often led to institutional suboptimization. Unfortunately, many of the information limitations of traditional information systems persist in today's enterprise administrative systems. Many educational institutions report that problems with data quality, ease of access, and integration are significant impediments to the use of institutional performance measures in planning, cost management, budgeting, and accountability systems. These information deficiencies challenge leaders faced with trying to create new, more efficient, and effective educational models, new revenue-generating enterprises, or effective planning for uncertain financial futures. Additionally, data quality issues are readily communicated to external accreditation bodies, regional or national comparison groups, or data requests from other parts of government and industry. In defining today's new educational institution executives, they need to view data and information as one of the core competencies within the knowledge enterprise, treating it like other major business infrastructures - telecommunications, information technology, student information systems, or finance and facilities management.

8.3.1. Data Silos

Data silos, which hoard data and make it difficult for applications and users to get the data they need, have different challenges in educational institutions. The most general feature of many applications is that they are built for administrative purposes rather than academic ones. They are aimed at automating a set of tasks and, as a result, have associated data that can be employed in that set of applications. If another application is required, a new database is created filled with its necessary data, creating a silo problem. This approach fails to provide the ability to integrate and report across the underlying applications and data. The rapid pace of technology change and tight budgets have often frustrated institutions' ability to share information across a campus. This creates a chaotic data environment that impedes quality data analysis required for insights, understanding, and data-driven decision-making. The initial concentration of data warehousing projects has been on efficiently gathering and organizing data for improved analysis in a single area.

Most institutions have now established a main data warehouse or have been able to bring together subsets of their silos into a set of data marts serving the management reporting and request needs of their users. One popular way to break down these silos is still in use: the creation of the data mart. Useful, but unlikely to solve the problem of creating an academic infrastructure that can reliably serve the institution's needs as a whole. There are a number of good reasons to question the data mart approach to the solution of the underlying problem with traditional points of integration at the data access layer. As more comprehensive enterprise modeling and architecture tools become available and understood, a more complete campus design emerges. The model allows the educational institution to optimize not just the data but also a skills model that grapples with the harder area of bringing the right skills to bear on those campus-wide projects.

8.3.2. Inconsistent Data Formats

With all the data compilation and analysis that is taking place in educational institutions across the country, it is hard to swallow that, for the most part, all of this effort is still being undermined by the inconsistent data formats from school to school, district to district, and state to state. It may sound like heresy to suggest that a stringent national or state uniform data structure is in order to deal with K-12. Most of the leaders at the district and school levels would rather that the solution be reached in some other way. No one wants some experts telling the folks in the field how to do their work. But the Department of Education now spends billions of dollars a year to help all students at the K-12 level, and there will soon be even more dollars available from the state level. Can these monies be spent in such a way that their results can be consistently assessed? We are already finding that we do not know enough about what works and what doesn't at the district and school levels. If we can change our data formats, we will not have a good sense of what is happening for some time to come.

Elements in our nation's K-12 data infrastructure are slowly beginning to fall into place. For example, state Education Management Information Systems are up and running throughout the nation, providing management data that has been extended to support state-required compliance data and national reporting on an annual basis. Some data standards have emerged to enable data exchange between school districts and other organizations seeking to pull data from disparate sources. The concern is that we are not really taking a comprehensive view of these issues that is rooted in concrete examples. This lack of vision is already starting to hamper and will limit the effectiveness of a host of related state and federal efforts, such as improving student achievement, increasing local management flexibility, and using human and financial resources more effectively.

8.3.3. Accessibility Issues

The need for comprehensive data architectures is even more important in higher education, as individuals with disabilities attend varying higher education institutions. Title II of the Americans with Disabilities Act applies to public institutions of higher education and mandates equal access for individuals with disabilities in higher education. The Americans with Disabilities Act and Section 504 of the Rehabilitation Act mandate that all students with government-recognized disabilities who are attending publicly funded universities must have equal access to information and that institutions should take steps to ensure the user-friendliness of web content for all users. A total of 456 research-extensive higher education institutions were examined to identify how many institutions address user accessibility within their web databases. It was found that public research-extensive universities from states with variable levels of accessibility mandates did not universally offer accessible PDF databooks. Therefore, designing accessible data access information systems for all stakeholders involved in accessing information is necessary to mediate individual, environmental, and institutional barriers. This primarily involves designing, developing, and deploying accessible technologies that comprise complete data architectures, information systems, and data books.

8.4. Key Components of Data Architecture

Data architecture forms the basis for the implementation of technology in support of an organization's mission. The components of data architecture include standard data models, data naming conventions, data element descriptions, data sharing definitions, and data distribution definitions. The use of these components allows different organizational components to produce and access data in a manner consistent with the meaning of the data, resulting in more effective and efficient shared access and use of data among organizational components. This result is critical in a large, decentralized complex organization.

Standard data models express the relationship between data. These data models include the conceptual, logical, and physical data models. The conceptual data model represents the data needed to support a given business function. It is a high-level, user-view model used in discussions with users. The logical data model represents the business data with all business data elements, their definitions, and relationships. The physical data models represent an implementation of the business data as a database or as a flat file. They include internal system data elements used to implement the relational database management system such as primary and foreign keys or pointers to access data.

8.4.1. Data Governance

The term data governance is often used loosely. Yet in essence, qualitative data governance refers to establishing broad lines of accountability to ensure that data is fairly collected and effectively used, as well as ensuring that breaches of legal or institutional policy are effectively managed. This is a slightly esoteric description of what is, of course, a very practical set of processes, but the complexity of the practical requirements means that the general principles are often neglected. The essential feature of these broad lines of accountability is that they must specify the roles and responsibilities, the ebb and flow of authority, and the systems of reporting and control.

The concept of authority is crucial, and yet in the world of data, it has some novel forms. Legal authority is required because quite often data about individuals is being collected, used, and sometimes shared or published. This therefore implies that for every piece of data, the basis on which it is being held and who that data relates to is explicitly understood, and that data users comply with the local data legislative framework. Institutional authority is required so those individuals, informed by their roles, become explicit, and the systems that support the collection, management, and use of data are effectively designed. Accounting authorities clearly specify the rights of access to specific sets of data, rights to approve the introduction of new data collection, use and storage, rights to produce reports and publish data, and rights to use data for decision-making.

8.4.2. Data Integration

Third, data integration plays a role in how well educators trust and use technology. Information from a diverse set of systems often provides conflicting or inconsistent information. A comprehensive data strategy is needed to modify inconsistent data and allow it to be used efficiently while retaining intended meanings and resolving any discrepancies. Lastly, integrated data are used to reframe problems by often showing personnel that the cause of an initiative's flaw lies in another domain. Without looking at data across multiple sectors, this would be hard to identify. But the power lies in the ability to act on it together.

We are aware of one example of an educational institution using integrated data to change behaviors at their school. The institution was part of a program, and the students could take college courses as part of the high school curriculum. But the students had to identify which professional or service class they wanted to take before performing the required career weeks. Students often performed more than one career week because they had objectives to do so by aligning with potential professional partners. Data deficits have created biases in student activities, encouraging them to engage with other sectors after which they seek advice. With the integrated data, the educational institution made the pattern visible and was able to collectively act on it to change student behavior as advised by the professionals who created the career weeks.

8.4.3. Data Quality Management

The concept of data quality can be quite subjective, since it generally depends on a user's perspective. Data quality is a measure of how relevant a data set is to its purpose in a particular context, i.e., "For what is my data valid? Are the values of the data inherently consistent with themselves and with the world? How complete is my data?" Essentially then, data quality depends on the root definitions of a business, what is in some cases referred to as the "terms of reference." Responsibilities for data quality should be delegated to those most capable of understanding the operating context of data, which, in most institutions, would predominantly be the staff members populating spreadsheets. More general definitions of data quality in the business intelligence context specify some eight different dimensions of data quality, largely derived from the original Data Collection plan document, but with some slight differences.

In a related context, the role of data quality catalogues is noted, which are used for validating reports. These catalogues check expected numbers, whether any important data fields are null and, importantly, checkbox results for all KPIs. It is advised that the business is best articulated using a conceptual data model while data layer identity and their respective low-level data meta-macro attitudes to data serve as a guide to facilitate and expedite ensuring data quality. Some simple advice regarding data quality appears to be quite generic but has been used over many years: understand the data, know what's important, and act to improve independent of corporate cultural beliefs. It is also suggested that in addition to a viable and verifiable business analyst for data-intensive activities, the organization should consider either the creation of a specific data integration and qualifiers team within the business, or make specific data work an integral component of each team's responsibilities.

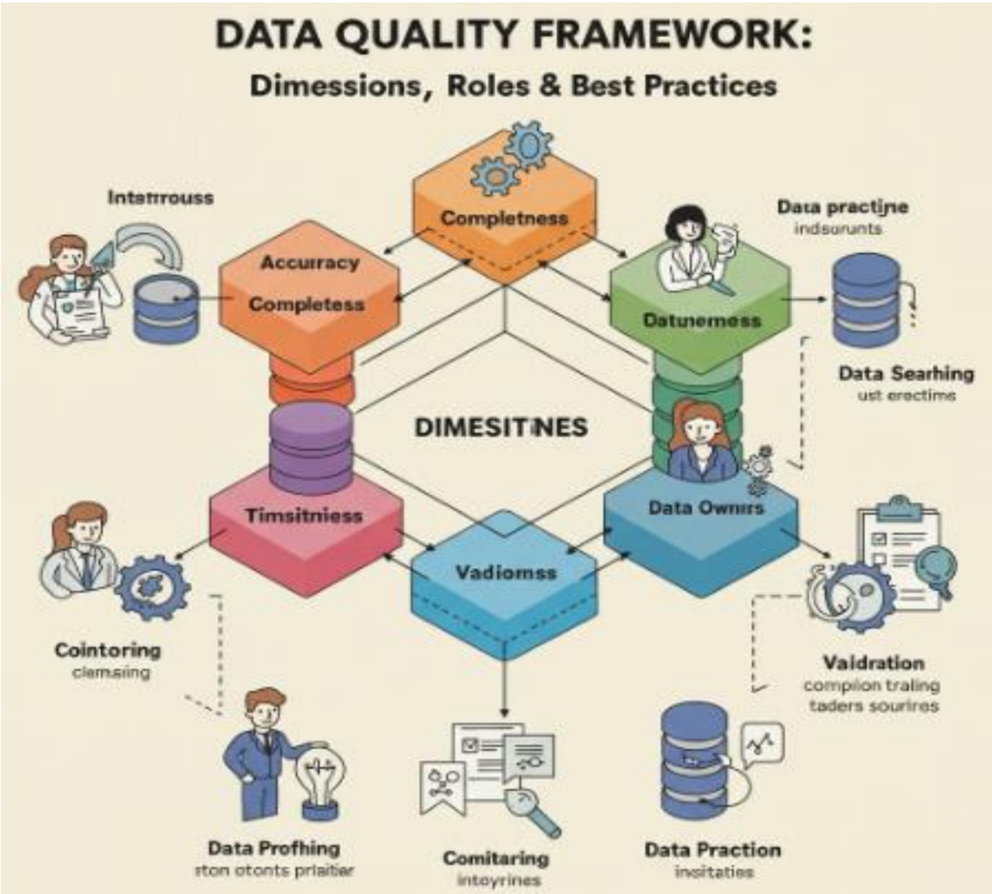

Fig 8 . 2 : Data Quality Framework: Dimensions, Roles & Best Practices

8.5. Frameworks for Developing Data Architectures

As this chapter has argued, despite the significance of high-quality data systems to generate the internal improvements and intrinsic funding logic of higher education institutions, there is currently a dearth of frameworks capable of guiding the development of well-architected, comprehensive educational data systems. Too many educational data systems are inadequately planned and managed and, as a consequence, have failed to deliver the kinds and quality of data that institutions need to operate effectively. There are therefore significant stakes for educational institutions in developing their capacity for the leadership and oversight of their data infrastructures. Depending on their goals, budgets, data capabilities, infrastructure, and staff knowledge and time, institutions looking to improve their data architectures are likely to face different sets of challenges and opt for different design and management approaches. However, effective approaches to policy drafting and decision-making in this area require a great deal of information, some analytical rigor, and a lot of flexibility given the range of both institutional technical capacities and strategic visions around prominent data projects.

This chapter developed a series of strategic planning and process models that higher education institutions could consider implementing as part of a broader framework or guide for the development of a comprehensive data architecture. First, it proposed institutional policies and mechanisms to guide the formation and ongoing management of data infrastructures. Such policies should connect educational data-driven processes and technologies to the institution's strategic vision and educational goals and should provide the baseline, guidelines, and the rules of the institution's data governance. Second, the chapter proposed the development of comprehensive data inventories and data maps as tools for improving institutional transparency and visibility over data activities and data assets. Third, the chapter proposed integrating data inventorying and mapping activities with an examination of the technologies that underpin institutional data systems and outputs. Fourth, the chapter proposed a series of models for developing comprehensive data system and capacity plans by integrating activities for system analysis and system modeling with opportunities for data useful disruptions and organizational change. Moreover, the chapter acknowledged some of the broader cultural and institutional challenges that the implementation of the proposed data architecture frameworks might face, arguing that a culture of learning and a norm of expanding data uses and users or beneficiaries are crucial for the sustained reputational growth and value of investment in organizational data assets.

8.5.1. Enterprise Architecture Frameworks

As the growth of information technology systems within educational institutions has increased, chief information officers and academic administrators within colleges and universities are faced with the task of realigning their information technology strategies and architectures with their institutions' long-term goals and objectives. In the past, institutions addressed information technology issues through the independent acquisition, implementation, and management of specific, standalone technologies. The expansion of web services and service-oriented architectures by schools further compounded this problem. We address how educational institutions could use enterprise architecture frameworks to develop and implement comprehensive data architectures that align their technology systems and architectures with their long-term strategic goals.

Enterprise architecture (EA) frameworks provide chief information officers and academic leaders with a structured approach to manage change by documenting, analyzing, and reviewing the components and relationships among information technology systems, including functional silos, data, applications, and infrastructures. EA also enables organizations to document, analyze, and visualize linkages between their information systems, data, and strategic business goals. Previous research has also discussed how enterprise architecture enables institutions to transform their existing repositories, models, data management roles, and governance from independent, stand-alone technologies and repositories to more comprehensive, enterprise-wide practices. Enterprise architecture frameworks include various established frameworks.

8.5.2. Data Warehousing Models

The last five years have seen numerous solutions for designing data warehouses as per the impositions of cardinality mismatches created primarily by hierarchical and network databases. However, the custom data warehouses are error-stricken and must be replaced for virtually any query that requires the generation of a grouping of rows that, if properly formatted, imitates the content of the multidimensional view of the data needed for effective decision support. In this text, we position cardinality mismatches within the lexical mismatches that can exist between computerized information systems and the data architectures that eventually create the business models, thus creating a unique label that weighs on the data warehouse market. We then suggest that developers and users will be better served if they revert to using custom coding methods, supplemented with object-oriented techniques, until someone designs an object-oriented programming extension to SQL and the relational model.

Despite the collaborative work in task forces and the conceptual and practical achievements of SQL and the relational model, in the absence of data warehousing, the semantics of the terms educational institutions and daily activities, from a computerized information system that supports enrollment and tuition modifications, are normally different. Both sets differ from the semantics and instances of the terms educational institutions and rows of a daily activity fact table, creating a business model for a data architecture capable of underpinning educational decision support systems. This is not good news because the intelligence and wisdom required to understand the needs of end-users and customers are either difficult to encapsulate or rely on business models that need to be represented, inheriting from sets other than themselves.

8.5.3. Cloud-Based Solutions

In cloud-based solutions, where various service providers and services might be used, the selection of the right service provider and the right service, along with the concerned contracts, becomes even more critical. For purposes such as transfer, permanent storage, or mere access, data are stored for various lengths of time. Accordingly, data should be stored in operations that are correctly managed, in environments that are nondestructive, in compliance with regulations in the sector to which the operations concern, the required continuity and service quality levels, and updated developments of service providers. Data should also be evaluated with the involved practices, without disregarding the fact that the organization might function or that some service providers might be unavailable within the scope of the agreements. Additionally, other mandatory legal regulations and precautions should be taken.

Data stored in cloud-based solutions with a remote access front and the requirement of service continuation would be defined more clearly, and the risks would be largely reduced if managed in the relevant data architecture, the relevant service providers are selected, and the concerned contracts are arranged in accordance with best practices. Educational institutions have a reasonable expectation to invest in this modern technology to continue the academic process without losing any data. The cloud has the potential to replace or improve upon currently available technology in schools and allow teachers and students to interact in ways now imaginable. The cloud also has the potential for schools to have fewer problems associated with classroom-based computers, such as hardware, software, and network challenges or issues. Educators can have all the resources they need when they are available in the cloud.

8.6. Best Practices for Ensuring Data Consistency

After reviewing a variety of proposed strategies for data management and having gathered broad acceptance of this model within the institution, a blueprint for the authoritative sources of all primary functional data must be created. The institutional leaders should appoint the team, produce a project plan, and allocate budgets to support data projects and initiatives. Adopting a data governance plan with a comprehensive set of data requirements provides the necessary checks and balances to guarantee data accountability, accuracy, integrity, and security. Users must also be provided with transparent and timely methods of reviewing and validating the data they depend on. Once data architectures and clear governance processes are in place, administrators at all levels, employees, and faculty members must be educated to understand the significance of data quality and data consistency and to follow established procedures. Maintaining a focus on data governance to manage data challenges will ensure the accuracy of information, streamline operational processes, and promote strategic initiatives. The goal orientation of individual groups must be accounted for as challenges are addressed since goals and timelines with financial benefits are essential to the success of a service. The highest level of data quality and consistency is achieved with clear and concise business policies that provide support for ongoing process enhancements, assuring data accuracy for institutional decision-making processes.

8.6.1. Standardization of Data Entry

To assure the accurate use of the collected data for planning future strategies to support the development of our institution and to meet governmental requirements, the university must standardize its data input, assuring that data are recorded correctly, consistently, and in a timely manner (Gadi, 2023; Burugulla, 2025; Challa, S. R., 2022). Actually, data are only useful if we know what the purpose of their collection is and use it to take some action. It is essential that we know who does what, who makes changes, who has access to data, and consider that one of the tasks of the Data Administration is to assure that we know how we look. Otherwise, we risk creating an extremely costly mistake that has serious and unpredictable effects. We need a national rule defining the name and meaning for each field value required for field information to assure accurate reporting of field information between educational institutions operating in the same country.

This national rule will help us to compare data fairly and to coordinate the educational goals and programs developed and taught at schools and colleges. Fortunately, we have already discussed such a national rule to be maintained that clearly reflects our diverse educational needs. We can do this easily because we have the data, and we have the information projects, project data, and information resources. We must confront what the community really needs, and the best way to serve the people. We agree with the idea that our students receiving Pell Grants should have a first-year retention rate of at least 75 percent and a 6-year graduation rate of at least 50 percent before any federal decision to list us in a group of colleges that perform poorly with respect to the future employment of their students. Then, we define the approach to be used by the national rule to maintain compatibility across educational institutions that allows us to meet all federal standards and external requirements for reporting field information.

8.6.2. Regular Audits and Monitoring

Regular audits and monitoring are essential to ensure that the data architecture implemented at the institution is performing as expected. It also ensures that objectives set in the long term have not gone askew. The internal audit team and the maintenance team at the institution need to look at transaction data, monitoring the fine working of the implemented data architecture. Regular checks could be put in place to ensure that report requirements of the institution are being met by the data architecture. This audit also extends to ensuring that reports are accurate and reflective of the original data. Any deviations from the original data, destroyed data, and/or variations need to be noted and corrected. Any errors or breaches in terms of handling the data done by the teachers or staff would also need rectification. Finally, a review of the existing data architecture would be needed on a regular basis. This would entail reviewing the objectives set, changing or adding to the objectives, and benchmarking best practices set in terms of data architectures in educational institutions and other institutions; cost-benefit analyses that were also originally set, to come up with suggestions for modifications and improvements while keeping the existing infrastructure in place, incorporating new suggestions and technologies. Data today and the associated technology are dynamic areas, and a regular review process is also essential to ensure that a data architecture meets current needs and future trends of the educational institution.

8.7. Ensuring Data Accuracy in Educational Institutions

Current definitions of data quality emphasize the importance of accuracy and consistency in the proper use of data (Challa, S. R., 2022; Pamisetty, 2024). Accurate data contain "no granular errors, internal contradictions, semantic qualities, and some data items may only be relevant for certain classifications or hierarchies—not all data items are relevant to the organization and the final consumers." In popular educational data models, the notion of correctness is expanded upon with the following factors: credibility (correct and complete data), accuracy (correct values), timeliness (collected and used at the right time), and interpretability (understandable and relevant to the task). Other popular educational data models add unique characteristics: relevance (appropriate data) and believability (agrees with the subject it represents). Independently of the education data model being used, regardless of whether it is for an institution, association, or initiative, the primary function of educational data is to be the foundation for various reports, analyses, and comparisons, as well as to provide a starting point for evaluating educational institution metrics.

In the domain of education, the accuracy of data is sometimes considered second in importance behind the completeness of data due to the fact that standard definitions and specific concepts about what constitutes accurate data are often not yet fully formed. As a result, many data quality deficiencies in the collection and management of education institution-related data have arisen, such as errors in the Family Educational Rights and Privacy Act, invalid student facility associations, and flawed graduation rate announcements. And yet, relevance and believability are also of great significance when educating the public about graduation or dropout rates. Educating others from within the field and outside the field about all the attributes affecting the accuracy of data at this point seems to be a more pressing need than collecting, evaluating, and solving these inconsistencies. Misunderstandings surrounding the meanings of student classifications are able to occur. Confusion occurred in the process of evaluating federal graduation rates. Recent "high stakes" testing brought issues related to the accuracy of data to the surface. Reacting to these situations in a display of efforts to ensure accurate data resulted in public appeals, summaries that recount warnings and responses from concerned parties, as well as investigation and correction, followed by reassessment practices. The user of education data is promised accuracy, but currently, educational data quality lacks formal definitions and systems. This deficiency presents a significant challenge for using data to shape policy analysis discussions.

8.7.1. Data Validation Techniques

Accurate data is very critical in any data-related project since it forms the foundation of intelligent decision-making. Therefore, one has to ensure that the data used is valid, accurate, and reliable. Data validation aims to ensure that the quality and fitness of the data meet the expectations of the data end users. It makes sure that the data is free of errors, unchanged, and consistent over time. Lack of data validation can spoil and pass invalid or incorrect data into a system, which in turn may damage the outputs of that information system. Therefore, in this section, we present various data validation techniques.

By using expert judgment, business rules, and the documented requirements, the accuracy and correctness of data can be improved. In the majority of cases, the best validation mechanism that guarantees a high standard of data is the manual method; that is, manual data entry and validation. This time-consuming approach is often the only way of verifying the accuracy of the data. The use of other validation techniques is to complement the verification process and improve, as far as possible, the accuracy of the data. When data is provided by individuals, data errors can occur. Data errors can also be caused by incorrect programming. For example, data entry screens must require all the information fields to have valid data. The date must comply with the proper format. Data elements that are mandatory, such as email, subject, and memo regarding the email procedure, must be included. Data validation is also necessary to ensure reliable data.

8.7.2. Error Correction Protocols

A great deal can go wrong in achieving the needed fidelity of data. Transaction systems often leave a trail of errors, discrepancies, and omissions, which can get built into the data shadow. Known results may become outdated, or newly developed methods may lead to changes in the definitions of the data elements. In formulas or algorithms used for neural network training or data mining, mistakes, bugs, or obsolete concepts affecting specific data elements may persist, even when they seem to be correct.

These sorts of data errors could be viewed as the rough edges of the collision zone between the familiar, buttressing world of classical information processes, databases, and transaction systems and the half-formed world of high-velocity data. Data editing for resolving conflicts, for removing ambiguity, noise, vagueness, or errors from data, and for otherwise vetting information requires a new set of principles, founded on a universal theory of data structures. While respectably difficult as software development tasks, the biggest challenges are essentially math questions and are amenable to the process of science. A variety of well-founded, statistically grounded error-reduction methods are relatively well understood, and complex, costly, accuracy-enhancing techniques are being taught in the engineering, computer science, and business curriculum of many universities. The most ambitious error correction needs to be bequeathed for future work. The most important nontrivial task, besides teaching available best practices, is conducting research that will improve the best practices with new methods and sensory principles. It would be useful to build a comprehensive taxonomy of the potential modes of reality-into-data discrepancies found in large-scale data shadow market systems. Data structures can in no way prevent errors from occurring within the information supply chain, but they can and should make discrepancies maximally discoverable and minimally tenable. At a minimum, every data structure's components should incorporate metadata that exposes the data's definitions, source, provenance, and trajectory. At most, they could incorporate heavy-duty methods that enforce consistency and accuracy.

8.8. Enhancing Data Accessibility Across Platforms

An essential goal of any data initiative should be to enhance data accessibility across platforms or to lower the barriers to entry for accessing and exploring institutional data. Many higher education institutions that implement data warehousing or business intelligence tools opt for a hub-and-spoke model of data transfer. In this model, data is pushed to these tools when adjustments are made to the schema, precluding the need for underlying data manipulation. This approach has a number of hidden costs: it often involves significant data redundancy, demands ongoing manual data upkeep, relies on expensive vendor licenses to manage data integration, and disincentivizes the "intelligent guessing" that underpins ad hoc data exploration. A more contemporary and cost-effective approach to enabling data exploration is to connect to data at source and to let users conduct manipulations where necessary and feasible. This can be challenging in an environment with disparate Student Information Systems and other domain-specific systems, but is essential for establishing a premise where data quality can be evaluated and improved. Data gatekeeping not only diminishes the potential for data discovery but also subverts the transparency that should underscore all data collection.

8.8.1. User-Centric Design

The design choices for any data architecture should always be user-focused. A data architecture must be easy and intuitive to work with. It must address the stated needs of

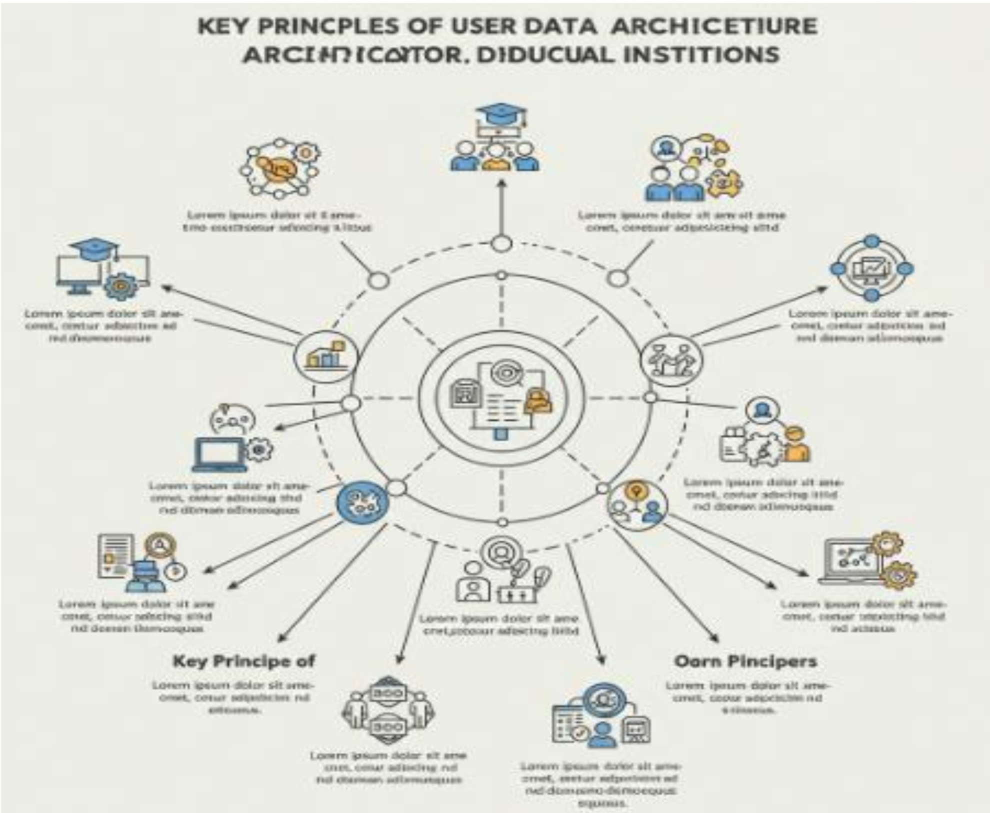

Fig 8 . 3 : Key Principles of User-Centric Data Architecture for Educational Institutions

the end users of the educational institution. The architects should realize that they may have to modify the data representation to conform to human insight. A good architecture only represents the data in a fashion most useful to its human user. It should be much easier to change the forms to suit the people than to force people into awkward forms. User-centric design follows certain established principles. Computers exist to serve human needs, not to control their users. The three most important attributes of an architecture are that it must be useful to the institution, it must be usable, and it must provide privacy. It must prevent the unauthorized use or the release of sensitive data. The design must give priority to the things that shape and are the consequence of human activities because this is the knowledge that the institution is attempting to capture. The architects should design for the relevant cognitive user representation – human concepts and perceptions, not an abstract mathematical model. This information will help to refine the architecture and inform policy making. In the final analysis, any structure that gets used will be better than a theoretically better structure that is ignored. A central point in user-centric design, which is direct architecture advice, is "People are their own most important resources; if the structures will not work for the people – they will not work."

8.8.2. APIs and Data Sharing

It is also beneficial to provide APIs, ideally RESTful APIs, to access, retrieve, and manipulate data. Not only should you provide APIs to access your data, but you should also ensure that APIs exist for other systems you might integrate with, such as student information systems, learning management systems, or identity management systems. When creating APIs, one should use standards-based technologies as much as possible and follow basic security principles, including token-based security.

In addition to providing API access, a supplemental mechanism is data sharing, which refers to sharing data with the educational institution community without requiring API calls. Although APIs give a data consumer tremendous flexibility, data sharing can provide good support for basic use cases. Data sharing can be offered by providing simple file download mechanisms for large datasets or by providing common dashboard configurations and field sets allowing for common data visualizations for analytics use cases. The general idea behind data sharing is to make common use cases very simple and decisions supported by available data, as much as possible, which will increase data usage rates. Data sharing could be offered through an existing higher education or K-12 data management entity to ensure broad access.

8.9. Conclusion

This study's prime objective was to present a reference architecture for educational institutions. The number of papers concerning data, information, and data mining for educational purposes has been increasing. The study's suggested reference architecture was an endeavor to aid analysts as a primary benchmark to be utilized when planning comprehensive, balanced, and neat architectures, aligning business with information technology through coherent and standardized structures. A total of 20 view models are suggested, categorized as structural, operational, and motivational. These models can be employed in a wide variety of information solutions, such as decision support systems and management information systems. The problems raised by the educational environment analysis can be costly due to the development of unsuitable information designs, thus possibly resulting in asymmetric solutions, above-average investments, or obstruction of information generation and therefore induction to the business.

The aimed results could be reached by conducting detailed awareness analysis on the involved stakeholders, group needs, and business constraints. Visual modeling represents a relevant stage in the organization planning. To conclude, architects should use models as a communication bridge, providing sight and unity to the business and to IT. Independent views have to be carefully overlapped in order to result in the fittest structure. Management support should be provided, associated with feedback mechanisms to facilitate consequent improvements. Technologies are important, yet they have to be tied to the higher-level organizational goals. The reference model can be considered by managers; viewpoints can be adopted and adapted to the targeted institutions' scenarios and culture, considering the specificities of elementary, middle, and higher education. The continued adoption of the reference model can ultimately contribute to reducing distortions and asymmetries, allowing the IT role to evolve, acting as a true business management supporter.

8.9.1. Final Thoughts on Advancing Educational Data Practices

Building comprehensive data architectures depends on developing the shared visions that clarify values and guide collaborative projects. Together, universities and colleges can develop rich sets of data assets that yield a virtuous cycle of deep, coherent insights about learning. The essential drivers, indeed the culture of collaboration, develop from constructive relationships, governance, and incentives among the members of those institutions. As shared data assets become more central to teaching and learning decisions, students, faculty, administrators, researchers, and the IT providers that offer services to them all will find new ways of deriving value. Ultimately, when university culture is adept at linking great data resources with astute governance and effective use, decisions and resulting actions lead to high-level learning for all students. Even as the distance from today's reality to the prospect of insightful, student-centered use of common, well-governed learning data may seem at first glance to be long, rankings frame similar challenges for higher education in the past few decades. It would not be difficult for educational IT practitioners to imagine a similar path of engagement leading just as comprehensively to deep and well-scored collaborative usage of educational data, to administrative, academic, and research advantages.

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