Government of Rwanda

An Architecture for the Integrated Education Management Information System

January 2020

Acknowledgements

The development of this Integrated Education Management Information System (IEMIS) Architecture and implementation roadmap is a major step towards improving the efficiency of education data production, analysis and use for decision-making and planning.

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Abbreviations

Term	Description
BNR	National Bank of Rwanda
BRD	Rwanda Development Bank
CPD	Continuous Professional Development
CRVS	Civil Registration and Vital Statistics
DDE	District Director of Education
DEO	District Education Officer
EDW	Education Data Warehouse
EFMIS	Education Finance Management Information System
EICV	Enquête Intégrale sur les Conditions de Vie des Ménages, in English, Integrated Household Living Condition Survey
EMIS	Education Management Information System
ESSP	Education Sector Strategic Plan
ETL	Extract, Transform, and Load
FAMIS	Formative Assessment Management Information System
GESB	Government Enterprise Service Bus
GoR	Government of Rwanda
HEC	Higher Education Council
ICT	Information and Communications Technology
IFMIS	Integrated Financial Management Information System
ILAS	Integrated Labour Administration Information System
IPPIS	Integrated Payroll and Personnel Information System
IPRC	Integrated Polytechnic Regional Centre
LARS	Learning Assessments in Rwandan Schools
LTMMIS	Learning and Teaching Materials Management Information System
M&E	Monitoring and Evaluation
MIFOTRA	Ministry of Public Service and Labour
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education

Term	Description
MIS	Management Information System
MDA	Ministries, Departments and Agencies
NEPS	National Examinations Publication System
NIDA	National Identification Agency
NISR	National Institute of Statistics of Rwanda
NST	National Strategy for Transformation
OLAP	Online Analytical Processing
RDB	Rwanda Development Board
REB	Rwanda Education Board
RGEA	Rwanda Government-wide Enterprise Architecture Framework
RISA	Rwanda Information Society Authority
RNRA	Rwanda Natural Resources Authority
RP	Rwanda Polytechnic
RRA	Rwanda Revenue Authority
RTMS	Real-Time Monitoring System
RURA	Rwanda Utilities Regulatory Authority
RWF	Rwandan Franc
SABER	System Assessment and Benchmarking for Education Results
SDMS	School Data Management System
SEO	Sector Education Officer
TMIS	Teachers Management Information System
TVET	Technical and Vocational Education and Training
TVET-MIS	Technical and Vocational Education Training Management Information System
UIS	UNESCO Institute for Statistics
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children's Fund
UR	University of Rwanda
WDA	Workforce Development Authority

Executive Summary

This Report discusses an architecture for an integrated Education Management Information System (EMIS) in Rwanda. Drawing on a desk review, an assessment of information needs and use, and an audit of the current information systems, the Report presents recommendations for a phased evolution to a policy and governance framework for educational management information system and an integrated architecture and.

Rwanda has one of the fastest-growing education sectors in Africa. Despite the progress, the education sector still faces a multitude of challenges ranging from poor quality, high dropout rates, low motivation, nutrition and feeding requirements for students from more impoverished families, poor reading culture, to gender inequalities in education. Improving access to education for vulnerable students, especially those with disabilities, is another challenge. Rwanda faces a significant shortage of teachers, with primary teachers often working two shifts, resulting in excessive work overloads. To address these challenges, the Government of Rwanda seeks to transition from merely tracking education coverage and access to understanding education quality and equity across different dimensions. To achieve this, the education sector needs data to respond to policy and planning questions and the changing reforms in the education system. Data are needed for: accurate financial management including budget and expenditure; planning of new schools; teacher management and development; tracking of the learning and teaching process; assessment of students' learning outcomes; school system performance measurement; and distribution of teaching and learning materials. Data can highlight differences between specific groups and allow decision-makers to design policies that ensure equity (e.g., equitable allocation of resources, gender equity, etc.). Data are also effective for expenditure projections, current resource allocations and regional and international reporting within the context of Sustainable Development Goals.

Efforts have been underway to develop databases across the education sector by the Ministry of Education, the Rwanda Education Board, the Workforce Development Authority and others like the Higher Education Council and the Rwanda Polytechnic. These databases are however function specific, do not communicate with other due to incompatibility of architecture and standards, and collect data independently. This is compounded by the fact that data is defined differently across the different systems, leading to inconsistencies in data about the same entity or statistic. All this is a result of the absence of an overarching national policy on EMIS.

Policies and procedures are the cornerstones of an integrated information system. Beyond the promotion of integration, the EMIS policy will define:

- The roles and responsibilities of different actors in data collection, verification, processing, extraction, management, warehousing and archiving.
- The schedule and time of data collection, management and dissemination.
- Training and capacity building on education data collection, management and dissemination.
- Technical specifications and interoperability and metadata standards to be adhered to during the collection and management of education data.
- Data privacy, confidentiality and use solely for the intended purpose.

- Framework for data ownership, sharing and coordination between MINEDUC and agencies and/or other institutions that require education data.
- Data dissemination tools to be available and maintained by all the institutions producing education statistics.

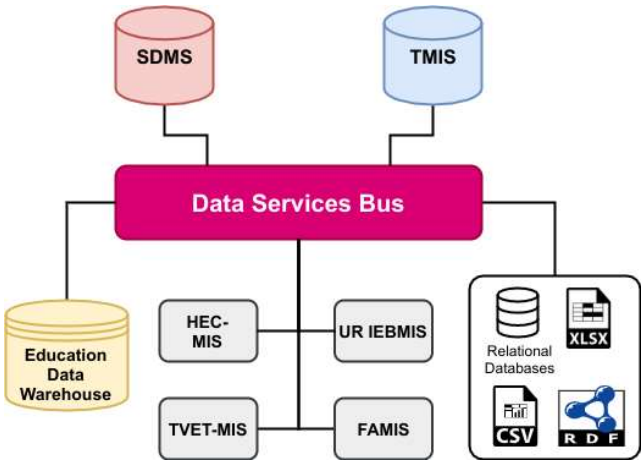
The development of a national EMIS policy is the necessary first step in building an integrated EMIS grounded in a shared vision

The integrated EMIS will be based on a high-level education reference architecture that conforms to the Rwanda Government Enterprise Architecture (RGEA) framework. This will result in a connected platform that brings together data from disparate sources and offers various services to different stakeholders, including those in other sectors that need education data.

Despite the gaps and challenges, the current systems as developed by different agencies are in a production environment, and each provides important functions. A two-phase approach that transitions from the current state to the required end state while ensuring business continuity was therefore recommended and agreed as summarised below.

Phase 1

Phase 1 will involve the upgrading of the School Data Management System (SDMS) and Teacher Management Information System (TMIS) as building blocks for an integrated EMIS with linkage to post-secondary education systems, including the Technical and Vocational Education Training Management Information System (TVET-MIS), Higher Education Council Management information System (HEC-MIS) and UR's Integrated Electronic Business Management Information System (IEBMIS) via a Data Services Bus. This will help drive digital transformation to improve access, quality and equity of education by leveraging technology and data in four key areas, namely—teaching and learning processes, professional development and empowerment of teachers, student support services and school administration. SDMS and TMIS are selected as a foundation because the two systems contain key registries of critical data that underpins operations across the four key areas above. SDMS has the most comprehensive data on schools, students and the curriculum while TMIS has the most comprehensive data on teachers.



Phase 1 will include the following activities:

- Upgrading SDMS to cater for all the necessary modules to meet the data requirements for pre-primary, primary and secondary education and adult learning.
- Upgrading of TMIS to cover both teacher administrative components (i.e, registration and management) and professional development components (i.e., practice, evaluation, and training).
- Data integration of UR IEBMIS, TVET-MIS, HEC-MIS and other external data sources through a Data Services Bus with the transformed data loaded into an Education Data Warehouse.
- Building analytical and query tools to create data view dashboards for different stakeholders interested in education data.
- Ensuring that the systems are built with open standards so that they align with the Rwanda Government Enterprise Architecture (RGEA).

In order to be successful during this phase and to minimise the proliferation of duplicate systems, a number of principles that should be discussed and agreed upon by all sector stakeholders. These include:

i. SDMS will be the primary interface through which schools provide any data that is required by all stakeholders across the education sector. SDMS will also be the authoritative source for school and student information as well as some curriculum information that underpins some of the registries in the Education Data Warehouse (EDW).
ii. TMIS will be the primary interface for recruiting and managing teachers at both district and REB levels. TMIS will also be the authoritative source for teacher information that underpins some of the registries in the EDW.
iii. National Examination Publication System (NEPS) functionality can be subsumed into SDMS where authoritative data exists on schools, students and different subjects that make up the curriculum. SDMS assessment functionality will be extended to directly capture student marks and grade for transition-level exams like P6, S3 and S6 as well as each student's unique index or examination number. REB and MINEDUC can provide user access to a subset of examination results via a variety of channels from the EDW.
iv. Learning and Teaching Materials Management Information System (LTMMIS) includes aggregate data that already exists in SDMS and TMIS. This data can be extracted from the EDW without the need for schools to directly input any data. As the sector moves towards digital learning resources, this system can be phased out over time. The school inspection/school performance monitoring module is powered by data collection forms that can be replicated in other data collection systems with prior authoritative data pre-loaded from the EDW.
v. Formative Assessment Management Information System (FAMIS) supports formative assessment of student learning using standard tests. The system can use authoritative student, teacher and subject assembled in the registries in the EDW. FAMIS can continue to host the unique data composed of question banks prepared by teachers and experts to assess student proficiency in different subjects. When students complete formative assessment assignments, FAMIS can send this data to individual student profiles in SDMS.
vi. Before building any new education systems, stakeholders will first consider extending current systems. They will only build new systems if they clearly collect new data, target new

data sources, or the new functionality cannot easily fit into existing systems.

Transitioning to Phase 2

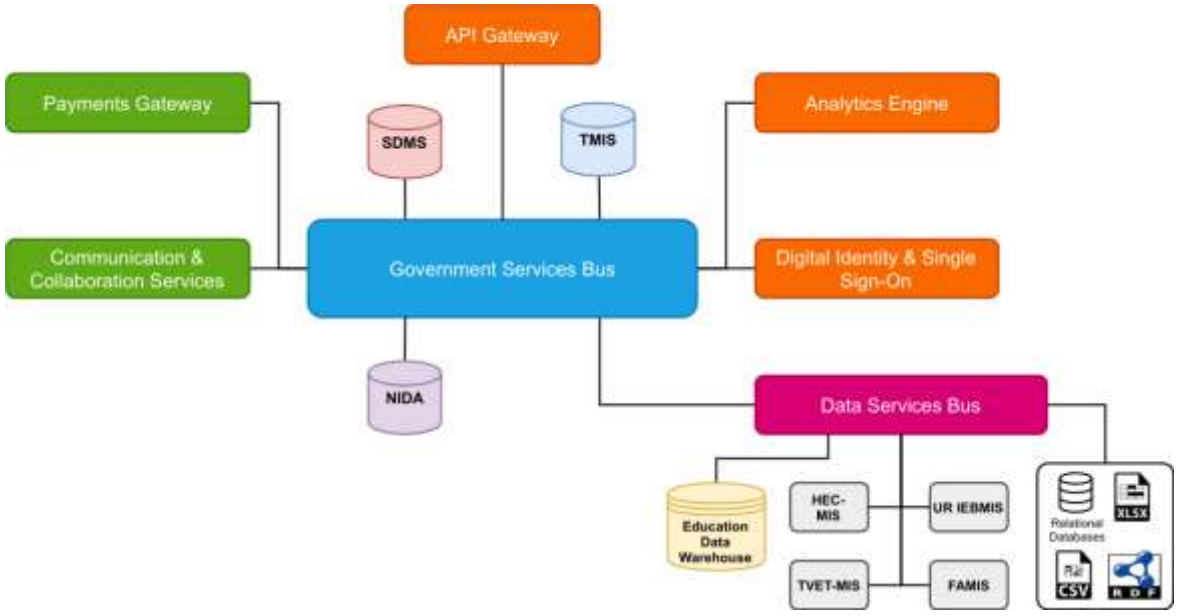
The following accomplishments that will signal improved maturity and collaboration among sector stakeholders and facilitate the transition from Phase 1 to Phase 2:

i. EMIS Policy developed and implemented.
ii. Education metadata and data dictionary that is recognised and used by different stakeholders in their data activities across the sector adopted and implemented.
iii. A Data Services Bus to integrate data from multiple selected systems and an Education Data Warehouse (EDW) platform that provides some mechanisms to visualise and interact with the aggregated data (analysis, dashboards, reports and visualisations) implemented.
iv. Dedicated EMIS Unit established at MINEDUC and able to maintain the EDW and use it as a means to integrate disparate data from across the education sector and beyond.
v. Basic interoperability standards that encompass both technical issues (see section **Error! R eference source not found.**) and policy issues (see section **Error! Reference source not found.**) that govern the seamless and secure exchange of education data across the sector adopted and implemented.

Phase 2

Phase 2 provides the ultimate integration of educational administrative data to learning resources information to monitor learning outcomes in near real-time, with a full linkage to other public sector data through the Government Service Bus. This phase builds on the successful implementation of activities from Phase 1, and assumes an environment that includes:

- Full school connectivity in order to access and provide data through an education cloud environment,
- Developed RGEA centralised services such as identity management and electronic payments that can be used to power government-wide online services.
- Seamless data sharing as well as applications and services reuse between educational entities.



Phase 2 will include the following key activities:

- Integrating EMIS components from Phase 1 into the Government Enterprise Service Bus (GESB). The combination of the GESB and the Data Service Bus will provide education data as a service.
- Developing a Digital Identity and Security component for the RGEA to interconnect disparate systems and provision access to a large number of users whose roles and privileges change over time based on the education calendar and cycle.
- Developing an Analytics Engine that uses Online Analytical Processing (OLAP) approaches to provide analytics and real-time event processing capabilities for reporting.
- Developing a Communications and Collaboration component for the RGEA to allow people, systems, and devices to communicate asynchronously.
- Implementing a local Education Cloud hosted at the National Data Centre to provide a hosting platform and a set of tools that allow different education stakeholders to create and provide new education services.
- Integrating with other RGEA components in existence such as a Payments Gateway that facilitates payments for government services through a wide range of payment channels or an API Gateway that facilitates access and use of APIs.

The following should be accomplished by the end of Phase 2:

i. Integrated EMIS has direct access to relevant data from systems of other government institutions such as the Ministry of Local Government (MINALOC), Ministry of Finance and Economic Planning (MINECOFIN), National Identification Agency (NIDA), Rwanda Revenue Authority (RRA), Rwanda Development Board (RDB), Rwanda Natural Resources Authority (RNRA), Rwanda Utilities Regulatory Authority (RURA), and the National Bank of Rwanda (BNR), that are already being piloted through the GESB via REST APIs or JDBC/ODBC connections.
ii. Different groups of authorised education data users can use one set of credentials to access

different systems across government or do Single Sign-On (SSO).

iii. Different education stakeholders and individuals can easily visualise and personalise relevant education sector-wide data by customising their dashboards using a graphical user interface.

iv. Integrated EMIS supports ability for user interaction via a wide variety of devices including mobile phones. In terms of communication and feedback, components support publishing of messages and allow users to subscribe and receive messages via a wide range of devices.

Implementation Cost

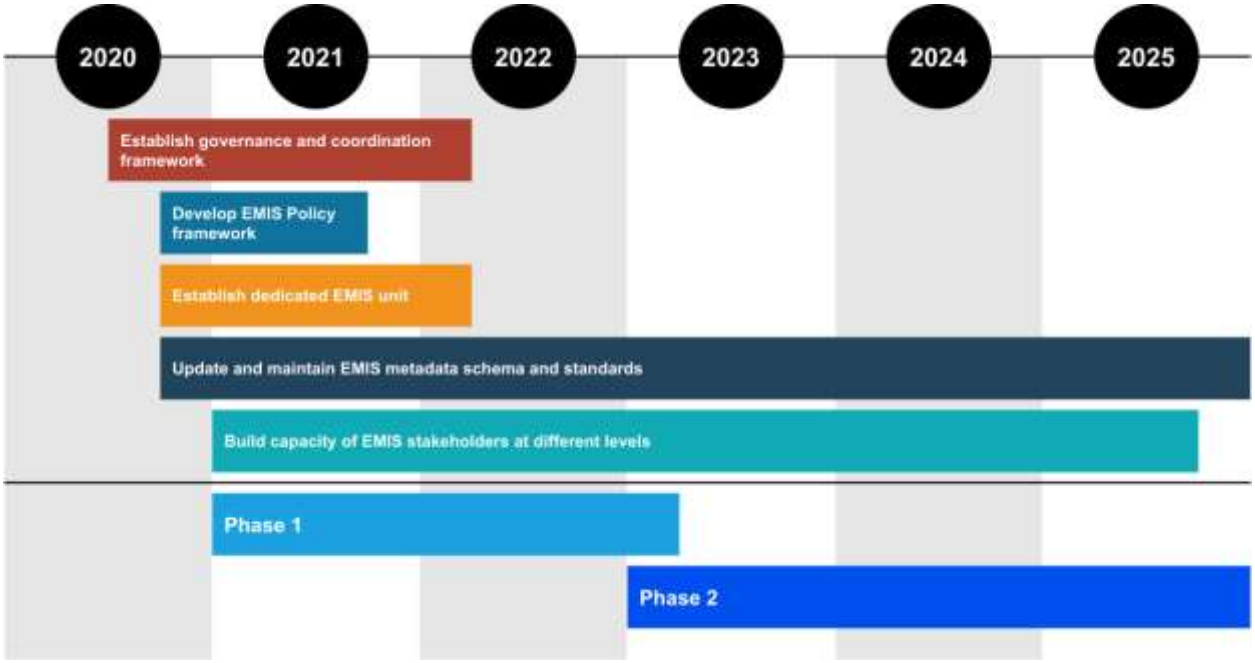
The main cost elements of each phase are summarised in Table below. Please note that the cost of each phase does not include the cost of other foundational roadmap activities (discussed in section 5) such as an EMIS policy, that will be implemented regardless. These are presented in the second half of the table.

Summary of cost elements

Category	Phase 1	Phase 2
Main cost elements	• Technical advice/support on databases management and integration: USD350,000 • Upgrades to SDMS and TMIS, Data Services Bus and EDW platforms: USD325,000 • Staff training and capacity building: USD150,000 • Storage and compute costs at national data centre: USD75,000	• Technical advice/support on implementing SOA reference architecture and integration: USD350,000 • Development, software platforms and tools, support: USD500,000 • Staff training and capacity building: USD150,000 • Storage and compute costs at national data centre: USD100,000
Total cost estimate of phase	USD 900,000	USD 1,100,000
Implementation timeline	2020-2022	2023-2025
Foundational roadmap activities that have to implemented regardless	• Developing EMIS policy framework to support the implementation of EMIS in Rwanda (USD 120,000) • Establishing a Governance and Coordination Framework for an Integrated EMIS (USD 116,000) • Establishing a dedicated EMIS unit at MINEDUC with support structure at other levels (USD 240,000) • Create EMIS metadata schema and standards (USD 120,000) • Capacity building and training for EMIS stakeholders at different levels: national, district and school (USD 290,000)	
Overall project cost estimate	**USD 2,886,000**	

Roadmap

The indicative implementation Roadmap, determined by both availability funding, will take five years


2020
2021
2022
2023
2024
2025
Establish governance and coordination framework
Develop EMIS Policy framework
Establish dedicated EMIS unit
Update and maintain EMIS metadata schema and standards
Build capacity of EMIS stakeholders at different levels
Phase 1
Phase 2

1. Introduction

This Report discusses an architecture for an integrated Education Management Information System (EMIS) in Rwanda. Drawing on a desk review, an assessment of information needs and use and an audit of the current information systems, the Report presents recommendations for evolution to an integrated architecture and a policy and governance framework for Educational Management Information System.

The education sector needs data to respond to policy and planning questions and the changing reforms in the education system. Data are needed for accurate financial management including: budget and expenditure; planning of new schools; teacher management and development; tracking of the learning and teaching process; assessment of students' learning outcomes; school system performance measurement; and distribution of teaching and learning materials. Data can highlight differences between specific groups and allow decision-makers to design policies that ensure equity (e.g. equitable allocation of resources, gender equity, equal education opportunities for people with disabilities, etc.). Data are also effective for expenditure projections, current resource allocations and regional and international reporting within the context of Sustainable Development Goals (SDGs).

Rwanda has one of the fastest-growing education sectors in Africa. The education system comprises four main levels: Pre-primary, Primary, Secondary and Tertiary Education, with a significant Technical and Vocational Education and Training (TVET) component at both secondary and tertiary levels. Emphasis is also given to Adult Literacy Education (ALE). Data from all these educational levels is important.

Despite the progress made, the education sector still faces a multitude of challenges ranging from poor quality, high dropout rates, low motivation, nutrition and feeding requirements for students from more impoverished families, poor reading culture, to gender inequalities in education. Improving access to education for vulnerable students, especially those with disabilities, is another challenge. Rwanda faces a significant shortage of teachers, with primary teachers often working two shifts, resulting in excessive work overloads. Efforts are underway to increase the number of teachers and to improve their skills and qualifications (MINEDUC, 2018; Williams 2017).

To address these challenges, the Government of Rwanda seeks to transition from merely tracking education coverage and access to understanding education quality and equity across different dimensions (MINEDUC, 2017). Efforts have been underway to develop databases across the education sector by the Ministry of Education (MINEDUC), the Rwanda Education Board (REB), the Workforce Development Authority (WDA) and others like the Higher Education Council (HEC) and the Rwanda Polytechnic (RP).

A broadly shared understanding and vision of an EMIS among participating stakeholders as indicated in Figure 1 is a precursor to building a comprehensive, integrated data management system and will be essential to guiding the modification of existing subsystems to meet the criteria of a good EMIS.

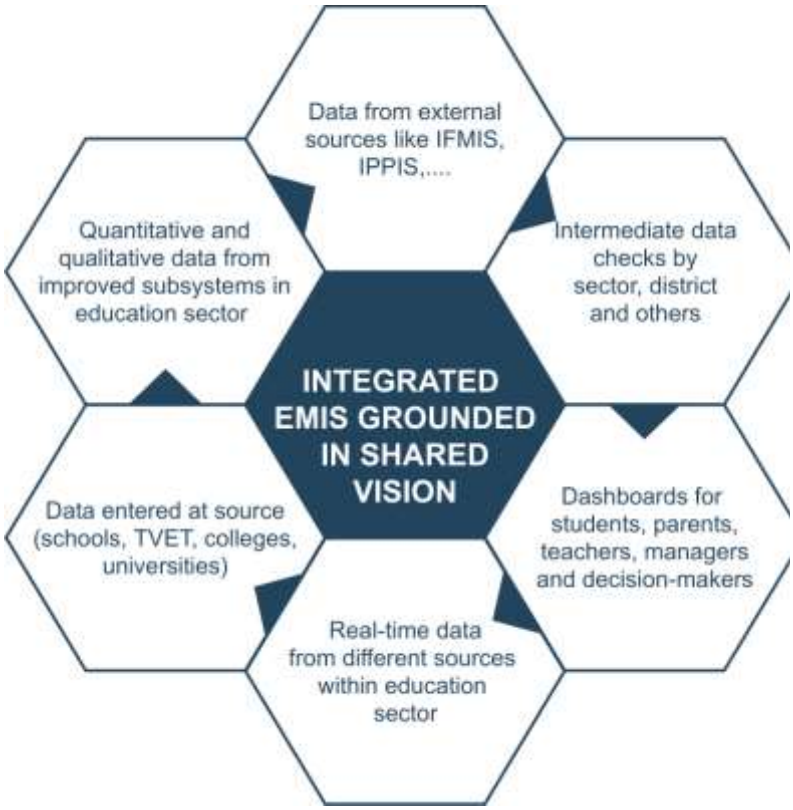


Figure 1: A model for an Integrated EMIS

Building a comprehensive and functional EMIS is not only about the technology and supporting infrastructure. It is mainly about people, processes and the culture that bring together various institutions that use the resulting information to deliver effective education at all levels (Adam, 2011).

The implementation of ICT in education involves not only the ICT components but also the policy, data and content management, data, IT governance, education standards, identity management, and security management. The degree of coordination and collaboration at all levels within the education system, as well as across government Ministries, Department and Agencies (MDAs) needs to be enhanced.

Figure 2 highlights that true integration goes beyond data to include the establishment of supporting policies, processes and organisational frameworks that minimise duplication while reinforcing quality, accuracy and accountability. It also entails skilling and motivating people at all levels (schools, sectors, districts and national levels) to collect, manage, disseminate and use data.

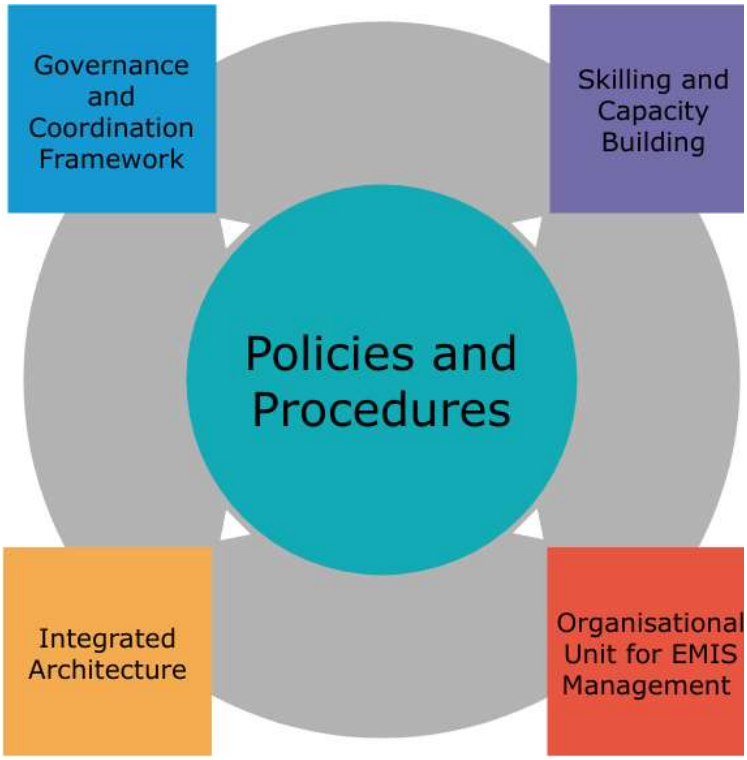


Figure 2: Building blocks for Integrated EMIS

An integrated EMIS can help drive digital transformation to promote access, quality and equity of education by leveraging technology and data in four key areas, namely – teaching and learning processes; professional development and empowerment of teachers; student support services; and school administration. Table 7 summarises the current and target states for each of these key areas.

Technically, the integrated EMIS should be built following enterprise architecture (business, application and technology) principles and the entire approach driven by the overarching SMART Rwanda[1] strategy, which has been taken into account in the recommended actions.

The rest of the report is divided into the following major sections:

1. Policies, Procedures and Frameworks for EMIS
2. Enterprise Architecture for EMIS
3. Towards an Integrated EMIS Architecture
4. Road Map and Implementation Plan
5. Cost Estimates
6. Summary
7. Appendix A: References
8. Appendix B: Datasets to support education business processes in Rwanda
9. Appendix C: Data tables for different entities.

1 Smart Rwanda Master Plan (2020): Towards a Knowledge Based Society.

2. Policies, Procedures and Frameworks for EMIS

Policies and procedures are the cornerstones of an integrated information system. In Rwanda, the proliferation of current data and applications implemented by different MDAs must be guided by national policy on EMIS. Beyond the promotion of integration, the EMIS policy will define:

- The roles and responsibilities of different actors in data collection, verification, processing, extraction, management, operational data store, warehousing and archiving.
- The schedule and time of data collection, management and dissemination.
- Training and capacity building on education data collection, management and dissemination.
- Technical specifications and interoperability and metadata standards to be adhered to during the collection and management of education data.
- Data privacy, confidentiality and use solely for the intended purpose.
- Framework for data ownership, sharing and coordination between MINEDUC and agencies and/or other institutions that require education data.
- Data dissemination tools to be available and maintained by all the institutions producing education statistics.

The absence of clear EMIS policy means that while a Sector Education Officer (SEO) holds a school Head Teacher (HT) accountable for data entry at the school-level, the data provided might not be consistent or come in at the same time across the country. Policies and procedures do not exist to define any consequences about failure to provide data or to accomplish this by a specific time. Furthermore, there are no rules with regard to the failure to maintain accuracy in data provision. Schools lack the necessary capability in terms of technical and human resources to provide accurate educational data on a timely ongoing basis. Other entities outside of schools and beyond the education sector that need to provide relevant data are not clearly defined. Processes to share data with other government departments and stakeholders like researchers do exist formally.

Additional policy gaps were also identified in the area of confidentiality. While schools can access EMIS data upon request, no mechanisms have been established to guide the flow of information back to the schools and communities. There is a need for a well-defined EMIS policy that has clear and explicit procedures and regulations to address the following:

- Types of data to be collected;
- Data collection processes;
- Data submission requirements;
- Data validation (internal and external);
- National, district and school reporting requirements;
- Responsibility, ownership of and access to data;
- Protection of student privacy;
- Maintenance and retention of confidential records;
- Technical specifications for EMIS and its subsystems;
- Allocating budgets or funding for EMIS and related activities;
- Procurement guidelines (if purchasing software/hardware from external vendors);

- The code of conduct for staff that collect and works with data; and
- Professional development for staff that work on EMIS and related activities.

The development of EMIS policy will require extensive stakeholder consultation in order to arrive at a shared vision and mutual responsibilities. An outline of an EMIS Policy is provided in Box 1.

Box 1: An Outline of the EMIS Policy for MINEDUC

- Definitions
- Preamble (introduction)
- Rational for EMIS in Rwanda
- Principles of EMIS
- Components of EMIS
- Supporting Legal Framework for collection, management and dissemination of information in the education sector
- Data for education
  - Data types
  - Data collection process – census forms, special request statistics
  - Procedures for collection of educational information
  - Data submission requirements
  - Data validation requirements
  - Data ownership
- Duties and responsibilities of schools, sectors and districts in the educational data cycle
  - Responsibilities of Parents and Guardians to Provide Information
  - Responsibilities of the Ministry of Education (MINEDUC) agencies
  - Role of Headteachers
  - Role of school information manager
  - Role of Sector Education Officer
  - Role of District Education Officer
- Education Information Systems Governance
  - Governance of the National Education Management Information System
  - Technical and Steering Committees of EMIS and their roles and responsibilities
  - Integrated EMIS
  - Responsibilities of the management of Integrated EMIS
  - EMIS Sub-systems
  - Responsibilities for management of EMIS subsystems
  - Shared responsibility
- The EMIS Unit
  - Role and responsibilities of EMIS unit
  - Role of the EMIS manager
  - Role of EMIS Unit staff
- Data dissemination
  - Data Privacy requirements and users' right management
  - Feedback to institutions on analysed information
  - District school profiles
  - School Education Profiles
  - Access to public
  - Data access for research purposes
  - Data warehousing

- Role of MINEDUC and other stakeholders
- Effective Date:
- Review Date:

3. Enterprise Architecture for EMIS

An Enterprise Architecture (EA) provides an integrated view of the education system, reducing the burden of costly mistakes arising from the use of diverse information and communication technologies in an unplanned and unstructured manner. An Enterprise Architecture helps to unify access to all content, provides cohesive user experiences and facilitates content, people and technology linkages. Enterprise Architecture development involves the identification of at least four core components:

- Business architecture that maps existing business processes in the education sector in the current state (as-is) and how they can be improved (to-be).
- Information architecture that maps information flows throughout the education sector and how they can be improved in the future.
- Application architecture that maps how the different software applications should interact now and in the future.
- Technology architecture that maps how core common services or registries will facilitate those interactions.

Furthermore, the enterprise architecture demands that organisations that establish information systems adhere to a series of principles. In all of the above areas the enterprise architecture begins with the analysis of the current state, followed by the definition of the future state. Comparing the two states will enable organisations to identify gaps between the two and to create a roadmap that outlines steps to bridge the gap in terms of implementation – in this case for information systems in the Rwanda education sector.

3.1 Current Architecture

In Rwanda, the current education data architecture is characterised by standalone applications developed to meet the different requirements of various institutions. To effectively use educational data, Rwanda needs to transition from independent databases consisting of data collected and managed by individual entities to building an integrated and comprehensive Education Management Information System (EMIS).

3.1.1 Business Architecture

Business Architecture encompasses the what, who, how, when and why of the sector's business. It describes the sector's strategic business intent (its vision, mission, goals and strategies) and how the core functions, processes, information and assets enact the strategic business intent. The current business architecture in the Education sector in Rwanda derives from the MINEDUC's mission, namely:

- Developing, reviewing and guiding the implementation of education sector policies and strategies.
- Enacting laws and adopting regulations and guidelines for the promotion of education.
- Developing and managing Education Monitoring and Evaluation systems.

- Developing strategies for resource mobilization and efficient utilization.
- Promoting the teaching, learning, and the good use of Information and Communication in Education.
- Developing, reviewing and guiding the education sector for institutional development and capacity.

The Ministry of Education (MINEDUC) works closely with other semi-autonomous Government agencies and Government ministries at central and district levels. These include the Rwanda Education Board (REB), the Workforce Development Authority (WDA), the Rwanda Polytechnic (RP), the Higher Education Council (HEC), the University of Rwanda (UR) and the National Commission for UNESCO (CNRU). The business functions of these institutions overlap with the core activities of MINEDUC, as summarised in Figure 3.

Figure 3: Core functions of different education MDAs

The assessment indicates that the business of education consists of primary activities and supporting activities. The primary activities of MINEDUC and the different agencies include:

- Development and execution of strategies, laws and standards to make education available to the broadest possible cross-section of the nation.
- Supporting schools, universities, colleges, academies or community groups that provide education and training.
- Development and management of educational institutions.
- Development and management of learning resources.
- Development and upgrade of the curriculum.
- Promotion of research and innovation.
- Monitoring learning outcomes across the entire education sector.
- Public relations including regional and international cooperation.

Also, MINEDUC and other agencies have other activities related to the management and upgrade of human resources, management of finances, infrastructure and assets, services and public relations. It is evident from Figure 3 that some of these core activities generally overlap across institutions.

3.1.2 Data Architecture

In Rwanda, data needs in education are governed by national and sectoral policies for education. Rwanda's current planning framework is the National Strategy for Transformation (NST1) covering 2017-2024 (GoR, 2017), while the overall direction for the education sector is outlined in a five-year

Education Sector Strategic Plan (ESSP), covering the period 2019 to 2024 (MINEDUC, 2017). Since Rwanda has designed her education policy objectives to promote access, quality, equity, and the development of skills and life-long learning as a vehicle to attain the desired knowledge and technology-based economy, education data must inform these core objectives. Moreover, education policies and strategies are aimed at addressing Rwanda's commitments to the Sustainable Development Goals (SDGs), the Africa Union (AU) Agenda 2063, and the East African Commission (EAC) Vision 2050. The data that are needed should also meet these external reporting requirements.

At the same time, data demands should be driven by the needs of a wide range of stakeholders including students, parents, teachers, head teachers, sector managers, district education officers and decision-makers within schools, colleges, polytechnics, universities and at national level. All of these stakeholders have different functions related to education and, therefore, different data demands. Table 1 summarises the core data needs across the education sector.

Table 1: Core Data Needs in Education

Data	Data Elements
Administrative data – data for operational purposes for promoting educational access, quality, equity such as quarterly, monthly and weekly records of attendance and movements of students and staff, salary payments, tests and examinations results, facilities, financial transactions, etc.	• Enrolment rates, including access, repetition, dropout, completion and transition rates for all level of education pre-primary, primary, secondary, Technical and Vocational Education Training (TVET), Higher Education Institutions (HEI); • Ratios, including student to teacher, school to student, classroom to student ratio, etc. • Assessment data (e.g., homework, examinations, marks, grades, report cards and transcripts) • English, Math, Science and Kinyarwanda proficiency • Adult formal and non-formal enrolment rate • Behavioural data, including absenteeism and late arrivals for both teachers and students • Special-needs population data • Administrative indicators such as efficiency, school development plans, teacher qualifications (e.g., age, agenda, etc.) • Assistance data such as school-feeding programs • Qualitative data to monitor school performance • Data on Quality of school leadership and management • School improvement program data
Infrastructure and asset data- data on schools or colleges infrastructure, population and resources available in the vicinity and within schools and colleges, school mapping, population projections, resource projections	• School mapping data using geographic tool • Facilities data (electricity, Internet, computer, WASH facilities, toilets, water, computer lab, infrastructure adapted to disability) • Number and characteristics of smart classrooms, ICT labs and ICT equipment • Use of ICT resources for teaching and learning • Digital content and online learning materials • Population data • Infrastructure and supplies data • Supply-side items such as textbooks, teaching

Data	Data Elements
	materials, desks, paper, and writing instruments
School feeding data	• Number of school children receiving daily meal at school desegregated by gender, grade and type of school feeding (porridge/meal/milk for day schools and breakfast/lunch/dinner for boarding schools) • Number and percentage of total "monthly" school days with school feeding per grade • Number of days with food served from at least 4 food groups • Type of food crop sources (school garden, local farmers, parents, local sources) • Parent contribution amount (RWF) per term per child and grade • Percentage of students whose parents, guardian or sponsor contribute to school feeding through cash per term • Percentage of students whose parents, guardian or sponsor contribute to school feeding through in kind contributions per term
Financial data	• Budget expenditure for schools, TVET, HEI and adult literacy • Research expenditure • Revenues • Spending • Cash transfers and subsidies (e.g., capitation and school feeding grants) • Unit cost per student
Learning Outcomes data - evaluation data on performance, efficiency and effectiveness of education service provision	• Internal and external efficiency • Grades pass and progression rates • Other rates, including completion, graduation, progression, and survival rates • National assessments results • Classroom assessments results • International assessments
Human resources data	• General demographics - Data on teaching and non-teaching staff, including administrative, management, security, janitorial, and cooking staff • Areas of expertise, turnover, promotions, awards • Number of researchers • Salaries • Performance evaluations • Professional development data for teachers and school administrators • Number of years of experience for teachers • Development courses, training, certifications, and allowances for teaching and nonteaching staff

While MINEDUC collects data that it uses to develop policies, strategies, laws, standards and regulations for education, the current information systems are not adequate to support planning and policy analysis. For example, data on the technology-enabled quality of teaching and learning are not readily available to inform the ESSP goals in this area. Further, the review indicated that:

- Different organisations have assembled multiple datasets from across the education sector, but in some cases, these may not tally. For example, Figure 4 shows the current dashboards from TMIS and SDMS. TMIS has captured 6,589 schools and 62,833 teachers, while SDMS has captured 4,358 schools and 73,625 teachers at the basic education level. On the other hand, the Annual Education Statistical Year Book for 2018 lists 7,535 schools and 76,865 teachers for the same level.

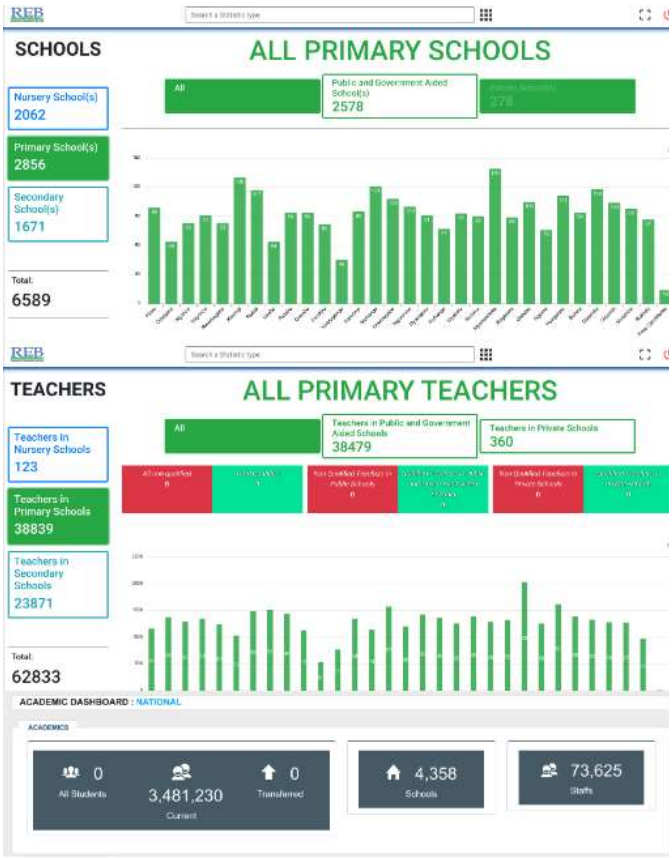


Figure 4: Sample dashboards from TMIS and SDMS

- The same kind of data is collected multiple times by different institutions at different times, from the same source; and
- Data definitions and metadata standards have not been agreed across the sector.

At an operational level, there is need to document the logical structure of databases within each current system by generating entity relationship diagrams (ERD). These will help stakeholders to visualise how education data is connected in a general way and will be particularly useful in constructing how data from the different databases can be merged or integrated to create the new data warehouse schema.

It is evident that there is a need for a complete set of data on students, learning outcomes, human resources, teaching and learning resources, research and innovation, infrastructure and assets, as well as special needs. Such data needs to be fully integrated to facilitate exchange and comprehensive analysis. A proposed Data Architecture is presented in section **Error! Reference source not found.**.

3.1.3 Application Architecture

MINEDUC and other sector players like the Rwanda Education Board (REB), the Workforce Development Authority (WDA), the Higher Education Council (HEC) and the Rwanda Polytechnic (RP) have invested resources to develop a wide range of information systems to support their work. Table 2 highlights key information systems that have been developed across the education sector.

Table 2: Current management information systems within Rwanda education sector

System	Function
School Data Management System (SDMS)	Captures student records and information, teacher records and information, school assets and infrastructure as well as student assessment and progression. Also includes module on school accounting system to monitor capitation grants.
Teachers Management Information System (TMIS)	Documents teacher information related to licensing, recruitment, placement, teacher transfer as well as basic evaluation, promotion and tracking CPD progress. Captures need for additional teachers from schools.
Learning and Teaching Materials Management System (LTMMIS)	Used to procure textbooks and educational resources and track their delivery across schools. The system also includes a module for school inspection/school performance monitoring.
Formative Assessment Management Information System (FAMIS)	New system to conduct formative assessment of student learning during school term using standardised tests. Can be used to track student progress compared to pre-set benchmarks of a new curriculum.
National Examinations Publication System (NEPS)	Students and parents can use system check examination results for P6, S3 and S6 online or via SMS.
Technical and Vocational Education Training Management Information System (TVET-MIS)	Captures TVET student admission information, registration as well as assessment and progression. The system also captures basic information on tutors, school infrastructure and the curricula across Integrated Polytechnic Regional Centres (IPRCs)
E-assessment system for teachers	A new system meant to provide an online avenue for teacher Continuous Professional Development at the national level. Based on Moodle, the system provides self-paced learning materials, allowing teachers to get certificates for completed modules.
Managing student bursaries and loans	HEC allocates bursaries and loans to Higher Education students using an old MIS from REB. Rwanda Development Bank (BRD) oversees the recovery of all loans from student beneficiaries and uses a different system, the Education Finance Management Information System (EFMIS). The two systems are not integrated.

An audit conducted on the current information systems showed that these multiple applications and systems do not communicate with each other, making it difficult to share data and improve functionality between them.

To effectively use educational data, the Government of Rwanda (GoR) needs to successfully integrate multiple kinds of data, from multiple sources within and external to the education system, and from multiple levels in the education system. This underpins the need to transition from independent databases managed by individual entities towards building an integrated and comprehensive Education Management Information System. Such a system should have the capacity to leverage school and college-based systems, data managed and owned at the sector and district levels as well as data generated at the national level such as the Integrated Payroll and Personnel Information System (IPPIS) and the Integrated Financial Management Information System (IFMIS).

Box 2: Main Challenges of the current Education Management Information System

- Multiple incompatible applications run by different organisations,
- Lack of binding set of rules, policies, standards or models to guide the collection and reporting of data across the entire education sector,
- Different data formats are required by existing sub-systems such as TMIS, LTMMIS, TVET-MIS, that makes data integration rather difficult,
- Lack of a shared metadata (data about data) and data dictionary on databases to ensure the common and harmonised meaning of educational data,
- Duplication of data with difficulty to harmonise, hurting data quality,
- Lack of adequate staff and institutional capacity to effectively manage, analyse and report on the data collected,
- LAMP (Linux, Apache, MySQL, PHP) stack is widely used across existing systems, except for SDMS that uses the LEMP (Linux, Nginx, PostgreSQL, PHP) stack. Integration between MySQL and PostgreSQL is technically feasible but requires metadata to make it easier.
- Limited provision for checking data quality across the systems
- Limited availability of ICT resources at schools, sectors and districts
- Despite the existence of many systems there is an absence of some crucial data that is important to measure progress in the education sector. For example, the current information systems are very weak in tracking assets, labs, learning objects, library resources, attendance, planning and scheduling and interaction between students, teachers and school management. A significant data gap also exists in the information that is relevant to assessment, human resources management, procurement and school inspection.

Currently, none of the systems has an active Helpdesk that would:

- Provide live support or a ticketing system to log incoming user requests across different channels; and
- Ensure that user requests are addressed in a satisfactory manner and that resolution performance and progress are tracked.

3.1.4 Technology Architecture

Table 3 summarises the various back-end and front-end technologies that MDAs have used to deploy the current information systems.

Table 3: Back and front-end technologies for existing systems

System	Back-End Technologies	Front-End Technologies	Other
School Data Management System (SDMS)	Fedora Linux, Nginx 1.10.2, PostgreSQL, Java (Spring Security, Spring MVC, MyBatis), PHP	JavaScript (jQuery, Easy UI, Angular.js, Moment.js, Bootstrap), Java, HTML5, Google Web Fonts, UTF-8	SSL certificate invalid (expired, issued for different domain) Hosted at AOS Data Centre
Learning and Teaching Materials Management System (LTMMIS)	Windows Server 2012, IIS/8.5, ASP.NET, SQL	Javascript (Bootstrap, jQuery, jQueryUI, Modernizer, SweetAlert2) HTML Transitional 4.0, Font Awesome, Google Font API, UTF-8	No SSL/TLS enabled Hosted at AOS Data Centre
National Examination Publication System (NEPS)	Windows Server 2012, IIS/8.5, ASP.NET, SQL	JavaScript (jQuery, Bootstrap), HTML 5.0, UTF-8	No SSL/TLS enabled Hosted at AOS Data Centre
Teachers Management Information System (TMIS)	Linux, Apache, MySQL, PHP	JavaScript (Bootstrap, Chart.js, jQuery, Moment.js) HTML Transitional 4.0, Font Awesome, Google Code Prettify, UTF-8	SSL certificate Hosted at AOS Data Centre
Technical and Vocational Education Training Management Information System (TVET-MIS)	Ubuntu Linux, Apache 2.4.18, MySQL, PHP, TYPO3/Mobirise CMS	JavaScript (Bootstrap, jQuery, jQueryUI, Popper.js) HTML5, Font Awesome, Google Font API, UTF-8	SSL certificate (expired sept 2019) Hosted at AOS Data Centre
Formative Assessment Management Information System (FAMIS)	Linux, Apache, MySQL, PHP, TYPO3/Mobirise CMS	JavaScript (jQuery) HTML Transitional 4.0, UTF-8	SSL certificate (expired sept 2019) Hosted at AOS Data Centre

It is evident from Table 3 that the LAMP (Linux, Apache, MySQL, PHP) stack is widely used across the different systems, except for the SDMS that uses the LEMP (Linux, Nginx, PostgreSQL, PHP) stack. JavaScript and HTML are used as front-end technologies across the board. Integration between MySQL and PostgreSQL databases is technically feasible, but the lack of metadata will make the exchange of data between such systems rather difficult.

Rwanda Information Society Authority (RISA) has initiated a Government-wide Enterprise Architecture. RISA provides guidance on hosting databases and education information systems for MDAs in the National Data Centre (NDC), helping to consolidate the technology and security architecture. The NDC is managed by a third party in partnership with the Government of Rwanda.

3.2 Target Architecture

A target architecture provides a business-driven plan that describes the desired end-state for its business architecture, data architecture, application architecture and technology architecture. It defines the core principles that will govern the different aspects of the architecture.

3.2.1 Business Architecture

A high-level target business architecture draws from the business processes of MINEDUC and her agencies discussed above. The information systems should be aligned with these business processes of the education sector. The core principles that govern the interaction between information systems and business processes are summarised below:

- Information systems should be designed to allow for Ministry-wide use, rather than use by a specific institutional unit.
- Information systems must always strive to provide maximum value to the institution while balancing the long-term costs and risks.
- All agencies and the departments of MINEDUC that participate in information systems development need to work together to accomplish the business objectives of MINEDUC and the education sector.
- Educational Management Information Systems need to be planned and maintained for uninterrupted operations.
- Information system management processes must comply with all relevant contracts, laws, regulations and policies of the Government of Rwanda.
- The risk to information and information systems must be assessed to ensure an acceptable level of integrity, confidentiality and availability.
- The EMIS Unit (which is expected to be established) is accountable for all information systems in the education sector. This accountability extends to the development and management of information systems and infrastructure that meet user-defined requirements for functionality, service levels, costs and delivery time.
- All subsystems that are built by different institutions should adhere to the integrated EMIS and overall enterprise architecture.
- All information systems and processes need continuous review and improvement in order to stay relevant.

The business of the education sector in Rwanda draws from the mandates of MINEDUC and other agencies like REB, HEC, University of Rwanda, Rwanda Polytechnic and the WDA. Based on the function of these institutions, the core business functions include:

- Development and execution of strategies, laws and standards to make education available to the broadest possible cross-section of the community.
- Supporting schools, universities, colleges, academies or community groups to provide education and training, research and learning process.
- Further development and management of educational institutions.
- Development and management of learning resources.
- Development and upgrade of the curriculum.

- Promotion of research and innovation.
- Monitoring learning outcomes.
- Public relations including regional and international cooperation.

The above core business functions require school and performance data as well as external social and economic information. In support of the schools, colleges and universities, the education sector needs data on assets, human resources, and finances.

3.2.2 Data Architecture

Data is an important asset of the education sector and, therefore particular attention needs to be given to the data architecture. The target data architecture needs to adhere to the following principles:

- Data is an asset to the education sector, being the foundation for decision making, and also supporting teaching, learning, research and administrative functions. It, therefore needs to be managed carefully to ensure reliability, accuracy and usability.
- Data is captured once and shared across the Ministry-wide departments and agencies. Duplication of data is not be allowed.
- Data must be accessible in order for students, parents, teachers, headteachers, district education management, policy and decision makers as well as other concerned stakeholders to perform their functions.
- Data are defined consistently throughout the education sector using a common vocabulary and metadata definitions. The definitions are understandable and available to all users.
- Secure data practices are used to avoid inappropriate disclosure of sensitive or personally identifiable information and to prevent unauthorised access.
- Each data element has a Data Custodian accountable for data quality.

Based on the above principles and the business processes of the education sector, data needs can be defined. Some of the core datasets needed to address educational business processes are collected under different data collection requests planned during the school year, which tend to be open for different lengths of time, as depicted in the EMIS data collection calendar. These may include:

- Event and attendance datasets – collect records that comprise a calendar of events and student attendance in order to validate contact hours in session and student attendance
- Student datasets – collect records to determine indicators like retention, drop-out, normal progression as well as for school accountability and funding requests
- Assessment datasets – collect data related to formative, summative and benchmark assessments
- Financial datasets – school financial data elements are reported in this dataset. It might also include data on forecasts.

Error! Reference source not found. shows how data from different datasets overlaps with different b usiness processes across the education sector. The data architecture enables the integration of the above datasets to meet the business processes of education sector stakeholders.

For integration purposes, educational datasets need to cease being institutional-specific, location-specific or even sector-specific. Figure 5 provides a conceptual model for education data that is compatible across the sector, which can support data portability for students across levels/schools and can support analysis and comparison of aggregate statistics. This encompasses:

i. Person – common attributes that allow model to represent individuals at different levels of education (e.g. student, teacher, parent/guardian)
ii. Organisation – entity not person (e.g., school, district, MDA)
iii. Role – time-sensitive affiliation between Person & Organisation to create People-Organisation relationships (e.g., enrolment, placement, class participation, etc.)
iv. Learning Processes – inputs, process steps, and outputs found at the intersection of educational organisations, people and learning resources
v. Time – relevance of data is constrained by time

Figure 5: Conceptual Model of Education Data

Table 4 shows how the conceptual model is used to define some of the key entities about which data can be collected across the education sector.

Table 4: Example entities to collect data about across education sector

Entity	Description
Student	A person for whom teaching, services, and/or care are provided in a pre-primary, primary, secondary and post-secondary educational program under the jurisdiction of a school, or other institution
Parent/Guardian	A person having parental or legal guardianship responsibility for a student
Teacher/Staff	A person who performs specified activities for any public or private school that provides instructional and/or support services to students or staff at the pre-primary level through upper secondary and post-secondary

Entity	Description
Organisation	An organisation, institution, agency, referenced to by schools, universities, Teacher Training Centres, TVET centres and Adult Literacy Centres, social services, or other education agencies
Ministries, Departments and Agencies	A national-level entity primarily responsible for policy, supervision, inspection, support, resource allocation, etc. related to education and schools at different levels
District	An administrative subdivision that oversees different types of schools within its jurisdiction
School	An institution that provides educational services, has one or more levels (pre-primary, primary, lower secondary, upper secondary) and has one or more teachers and a Head Teacher
Subject	The organisation of subject matter and related learning experiences provided for the instruction of students on a regular or systematic basis, usually for a predetermined period of time (e.g., a school term or a school year) to a group of students (e.g., a class)
Assessment	Entities and elements to support the design, administration, and evaluation of the results of assessments used to measure one or more persons' mastery of one or more learning objectives
Calendar	A set of dates associated with an organisation
Incident	A violation ranging from a minor problem or behaviour that disrupts orderly functioning of a school or classroom (e.g., arriving late to class) to a criminal offence that requires help from local administration and police officials (such as theft). A single event (e.g., a student fight) is one incident regardless of how many perpetrators or victims are involved

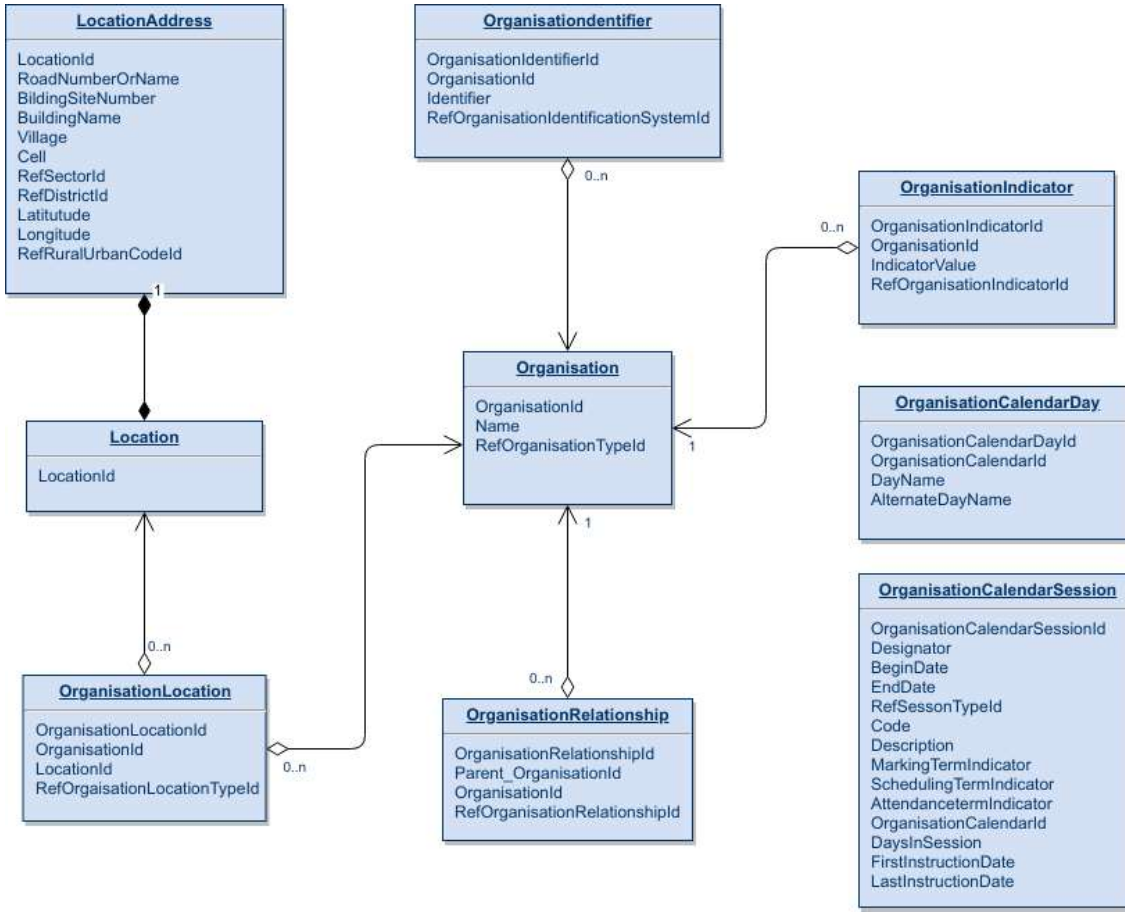


Figure 6: Organisation entity relationship diagram

Organisations are entities as depicted in Figure 6. In Rwanda, these include schools, sector education offices, district education offices, colleges, universities, adult literacy centres, MINEDUC and her agencies such as HEC, REB, RP, UR, and WDA. Organisation may also represent classes, sections and departments as well as campuses in schools and universities. Organisations have different types of relations, the most common being that of parent-to-child. For example, MINEDUC contains or oversees other Organisations. A complex set of relationships between Organisations is needed to accommodate or model the multiple hierarchies that exist within Rwanda.

People are another critical data item that needs to be consistent despite varying roles and relationships with organisations. A student in one institution maybe a teacher or employee of another institution. A person can be:

- Pre-primary education student
- Primary school student
- Secondary school student
- TVET student
- University student
- Adult Literacy Programmes Student
- Teacher/Trainer/Lecturer
- Administrative Personnel

- Head Teacher
- Parent

People attributes are associated with a particular Person-Organisation relationship or role. People tend not to have roles outside of their relationship with an organisation. A person is not a student unless and until they are enrolled in a school.

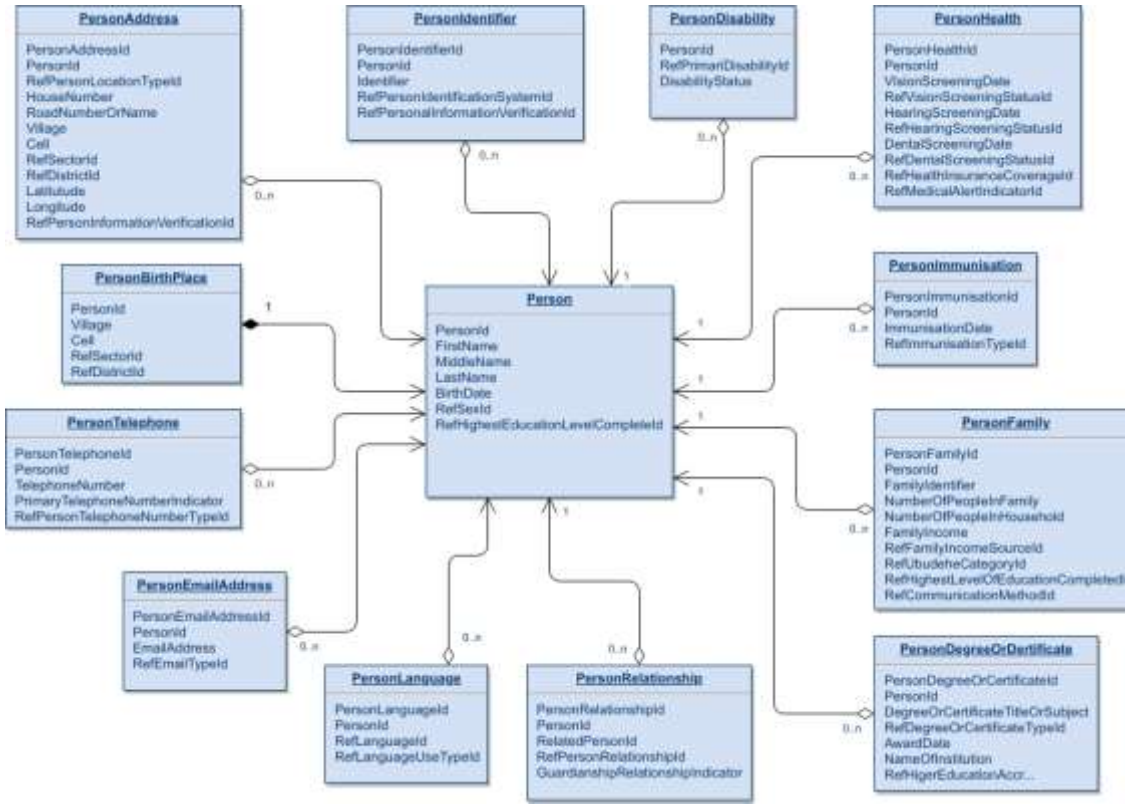


Figure 7: Person entity relationship diagram

People-Organisation Relationships contain a higher volume of data than all of the other relationships combined. It will hold a standard representation of each change in the relationship between a Person and an Organisation. Examples of these relationships include every time a student enrols in a school or changes classes at the end of the academic year or every time a teacher changes school assignment within a district.

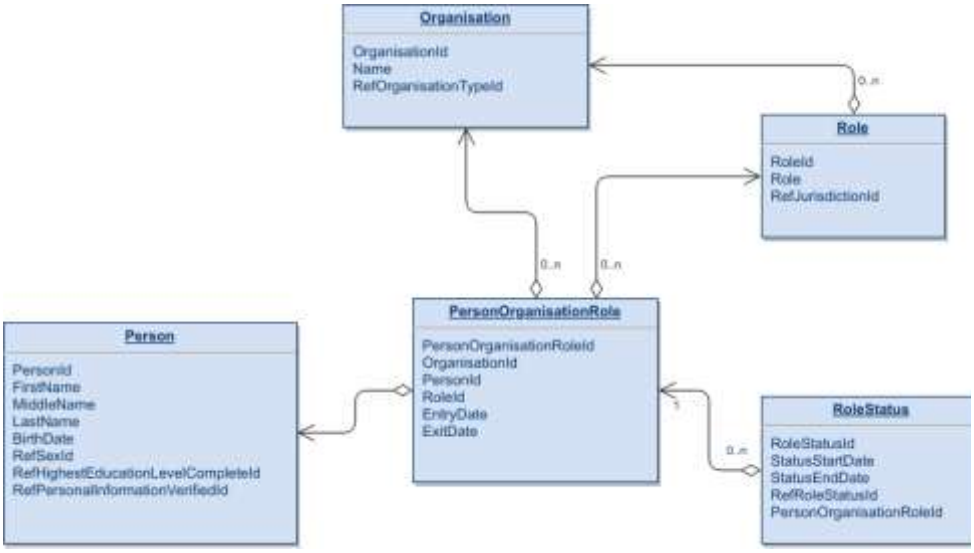


Figure 8: Person-Organisation entity relationship diagram

One particular type of Person-Organisation relationship of special note is the Student-Teacher link. The most common representation of the Student-Teacher link will be one in which the Organisation is a Subject with a Class within a School, with at least one teacher and a roster of students. This link is one way that we can relate student growth and achievement back to a teacher, allowing analysis of different teacher interventions. Figure 9 shows how teachers and students might be linked through a Class.

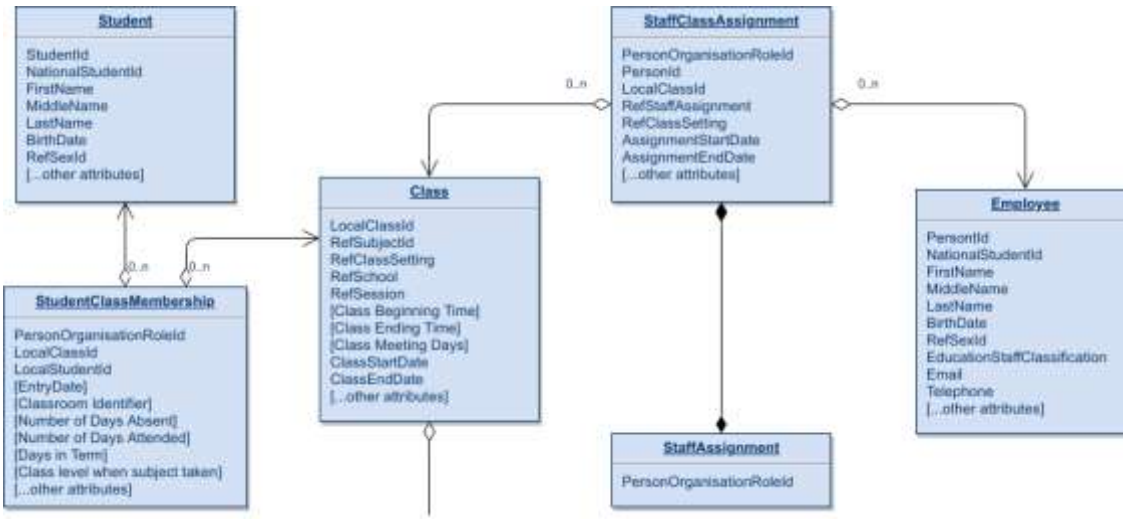


Figure 9: Example showing how teachers and students may be linked

Standards and assessments are other data entities that have relationships with people and organisations. Events that have a common relationship to time are also important data items. In general, events happen to individuals on a particular day and may include:

- Attendance
- Graduation
- Placement

- Annual Review
- Promotion
- Termination
- Suspension

The analysis above indicates that data architecture requires:

- Identifications of the datasets that serve the business process of education, as shown in **Error! Reference source not found.**.
- Establishing relationships between data entities to facilitate integration between different data elements, namely – datasets, people, organisations, people-organisation relationships, standards and assessment and events and indicators.

A schematic diagram representing the interaction between these data elements is summarised in Figure 10.

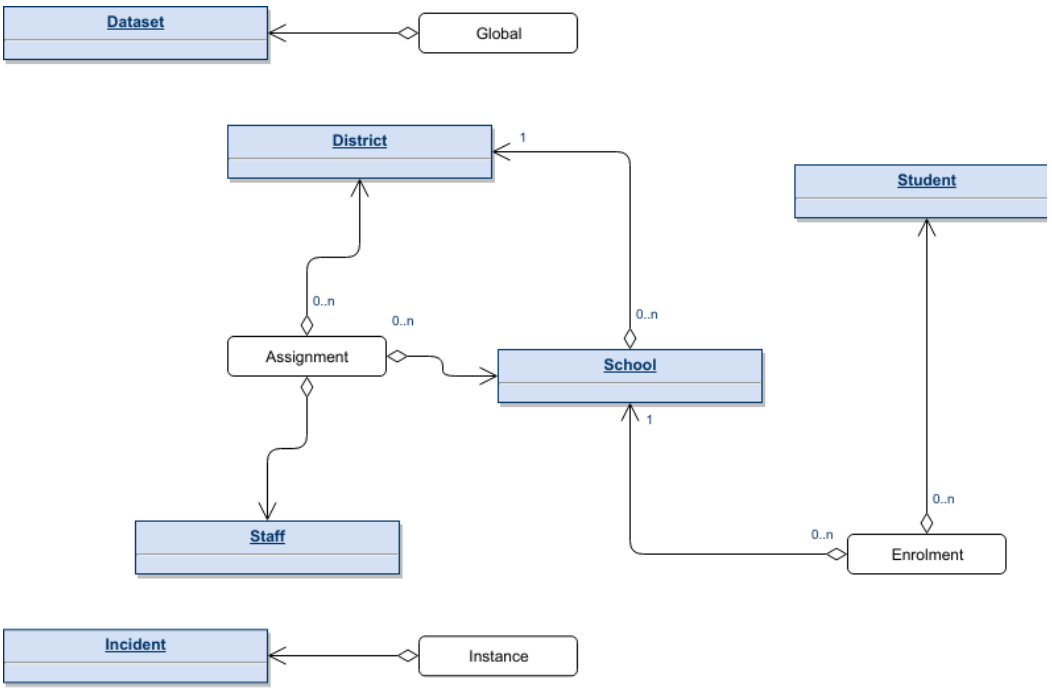


Figure 10: Interaction between different entities

Error! Reference source not found. highlights some of the key educational business processes and t heir related data. Datasets do vary across education levels because of underlying differences in program duration, curricula, financing, research requirements and other factors. Each dataset needs underlying metadata that describes its characteristics (e.g. name, version, content) and shed more light on the context and structure of records when different activities occurred (e.g. data source, location, date, and time), entities involved (e.g. teacher ID, student ID and subject ID) and who captured the data (user ID).

A solid data integration schema involves ETL (Extract, Transform, and Load) definitions for a variety of data collection and integration mechanisms. These include file-based imports, database connections, School Interoperability Framework (SIF)-based connections and Web Services-based

communications. Automating these connections—to whatever degree possible—is the key to ensuring that this enterprise architecture remains synchronised with the various applications, services, and content providers that make it up.

3.2.3 Application Architecture

The target application architecture brings the sub-systems of Education Management Information Systems into one integrated system. The target architecture needs to adhere to the following principles:

- Applications are open and independent of specific technology options and, therefore can operate on a variety of technology platforms. This implies that the sub-systems and integrated EMIS should be built on open standards.
- The information system architecture is built with modular, reusable (plug-n-play) components that implement services.
- New applications should be built, taking the education-wide Enterprise Architecture into consideration.
- The external providers need to adhere to the education-wide and Rwanda Government Enterprise Architecture.
- Applications need to adopt a mobile-first strategy for providing access to different stakeholders that inherently use mobile handsets as a basic tool for access to information.
- Applications must be planned to reduce the impact of technology changes and vendor–dependence on the business processes.
- Applications need to be easy to use. The technology should be transparent to users, so they can concentrate on their objectives rather than on their interaction with the systems.

Applications developed need to meet the business requirements of the education sector, as discussed in **Error! Reference source not found.**. An integrated EMIS should be able to provide the k ey functionality requirements of an enterprise application, namely:

- Customer-facing functionality (customer relationship management, personalisation services, online help service, etc.)
- Process automation functionality (tracking workflow, case management, inbound and outbound correspondence management and routing and scheduling.)
- Business management functionality (change, configuration, quality, risks and requirement management, supply chain management and Organisational management services)
- Digital asset management functionality (content review, tagging and aggregation, document management services, knowledge and records management services)
- Business analytics functionality (analysis, visualisation, knowledge discovery and reporting)
- Back-office functionality (data management, human resources management and financial management services, security management, collaboration, query and search services)
- Communication and support functionality (communication, systems management,

forms management).

An integrated EMIS should be built with a series of information systems that address the different education business processes. Based on these business processes, the main modules that underpin an integrated EMIS can be defined. These include:

- School information;
- Student information;
- Attendance monitoring;
- Student assessment;
- Student feeding management;
- Learning management;
- Discipline management;
- Student counselling and guidance;
- School timetabling, scheduling and events;
- School accounts and payments;
- School inspection;
- Human resource management (teaching and support staff);
- Student/parent communications;
- Teacher processional development;
- Curriculum management;
- Digital content management (teaching and learning resources);
- Infrastructure and asset management; and
- Policy and strategy monitoring (ESSP tracking).

While the SDMS attempts to fulfil the integrated EMIS function, it does not cover all business processes of the education sector. The Teachers Management Information System (TMIS), the Learning and Teaching Materials Management System (LTMMIS) and the new Formative Assessment Management System (FAMIS) do address important areas like human resources management, learning resources management and formative student assessment respectively. The University of Rwanda's Enterprise Resource Planning system, known as Integrated Education and Business Management Information System (IEBMIS) and the Technical and Vocational Education Training Management Information System (TVET-MIS) do address critical business processes at the tertiary education level.

Table 5: Gap between current systems and desired modules for EMIS

Desired Module for Integrated EMIS	Current System
Policy and strategy monitoring (ESSP tracking)	---
School information	SDMS
Student information	SDMS
Attendance monitoring	---
Student assessment	SDMS (basic functionality), FAMIS
Student feeding management	---
Learning management	---

Discipline management	SDMS (basic functionality)
Student counselling and guidance	SDMS (basic functionality)
School timetabling, scheduling and events	---
Infrastructure and asset management	SDMS (basic functionality)
School accounts and payments	IFMIS, SDMS (in pilot)
School inspection	TMIS (basic module for data collection)
Human resource management (teaching and support staff)	TMIS, IPPIS
Student/parent communications	---
Teacher processional development	TMIS (basic functionality)
Curriculum management	---
Digital content management (teaching and learning resources)	LTMMIS (biased to physical textbooks that are being phased out)

Table 5 highlights some of the areas that need to be addressed. These include:

- Policy and strategy monitoring (Education Sector Strategic Plan monitoring and tracking)
- Attendance monitoring (ability to capture school and class attendance through the school year)
- Student assessment information (capture student performance for both formative and summative assessment)
- Curriculum management (automate processes and procedures for maintaining up-to-date information about subjects as well as quality monitoring)
- Infrastructure and asset management (capture beyond basic data at school-level and facilitate maintenance and future planning at district-level)
- Human resource management (capture teacher experience and development, measure teacher effectiveness at the school-level and facilitate management and IPPIS integration at district-level)
- School inspection (monitor school quality by providing advice to support improvement and accountability)
- Digital content management (manage life cycle of digital learning assets regardless of type and format or their method of delivery)
- Student/parent communications (share school information with students and their parents or guardians and give them avenue for interaction with the school)

3.2.4 Technology Architecture

The technology architecture defines a common, standardized vocabulary, allowing better discovery, collaboration and interoperability among institutions involved in the education sector. The use of common technology and tools will allow all education stakeholders to benefit from economies of scale through identification and re-use of the best solutions and technologies to support the business of education. A good technology reference architecture typically covers the following items:

- Data management services that provide needed frameworks and methods to ensure the security of data and information.
- Business application services that provide needed software or business applications that are used by business users to perform various business functions.

- Infrastructure services that provide the basic core that support applications that are visible to most users (whether cloud, internal, or external). Infrastructure services is comprised of virtual machines, physical machines, applications, databases and both internal and external cloud services.
- Security management services that provide frameworks and methods of operation to ensure the security of information.

Typically, the technology architecture comprises a series of components including applications services, infrastructure like access channels (mobile and web service) and service delivery channels such as the Internet and virtual private network and authentication requirements. The technology architecture also defines platforms such as servers, hosting and storage, security, presentation and other requirements for application integration and interoperability. The core components include:

- The application, information and web components that promote common development and presentation standards enables optimum system integration, including opportunities for the use of shared infrastructure, servers and storage and shared use of data. The application and information components facilitate the reuse of different libraries and tools and the rapid deployment of applications in response to changing business requirements. Open standards and open source applications will have precedence to custom development efforts.
- The platform component that defines the technical components of the infrastructure including, server and client platforms, middleware, operating systems and interfaces supported, as well as other software tools and equipment used to operate applications. These include LAN based network servers, PCs, laptops, workstations and storage area networks. It is recommended that the MINEDUC and stakeholders adopt the latest open standard platforms and infrastructure.
- The network components that includes voice and data technologies, as well as various network topologies, transmission services and protocols necessary to facilitate the interconnection of server platforms, intra-building and office networks (LANs), and inter-building and campus networks (WANs).
- Internet infrastructure component that enable services and information readily accessible and available to the public, with interactive services to conduct business. This component also provides mobile access that enables greater interaction and service delivery.
- Cybersecurity component that defines and enforces the security standards and policies necessary to protect the information assets and technology infrastructure. This component provides an appropriate level of protection for all educational information processing resources, regardless of platform, and includes incorporation of industry best practices to yield an overall reduction in risk.

In addition, the technology architecture requires that institutions adhere to technical and semantic interoperability standards, that are reviewed and updated over time to ensure alignment, consistency, and modernisation in the selection and design of business solutions for the education sector.

3.3 GAP Analysis

The lack of coordination in information systems development by institutions across the education sector represents the major gap between the current and target environment. This has implications for choices related to data, applications and technologies. The lack of metadata and a common vocabulary means data sharing and integration is difficult and complicated. There is a need for an agreement to come up with a common vocabulary, metadata, data standards/formats and templates for use across institutions within the education sector. Table 6 highlights the gap between the current state and the target state.

Table 6: Summary of the gap between current and target state

Architecture	Current Architecture	Target Architecture
Business	Information systems were designed to meet the requirements of different institutions like MINEDUC, HEC, REB, WDA, RP and UR.	An integrated information system and data to support the education business process are proposed.
Data Architecture	Metadata and data vocabulary are not fully defined and used upon sector-wide.	Data is aligned with the business process of education. A process for the creation and adoption of existing educational metadata is proposed.
Application architecture	Applications are inadequate to support the education business process.	The target application architecture provides an integrated view of applications to be developed to meet the education business process
Technology Architecture	Technology is implemented without regard to common standards and an interoperability framework. RISA provides sector-wide infrastructure.	Interoperability standards to be adhered by educational institutions to promote the integration of information systems are available.

An integrated EMIS will also help drive digital transformation of Rwanda's basic education to promote access, quality and equity of education by leveraging technology and data in four key areas, namely:

i. Teaching and learning processes;
ii. Professional development and empowerment of teachers;
iii. Student support services; and
iv. School administration.

Table 7 summarises the current state and the target state for each of the above key areas.

Table 7: Digital transformation for Rwanda's basic education

Transformation through integrated EMIS	Current state	Target State
Enhance Learning Outcome through students' participation	i. Most schools predominantly support a physical teacher-in-class form of learning delivery ii. In terms of equity, schools do not capture teaching and learning environment variables particularly for students with special needs iii. Assessment "of" student learning usually happens at the end of the school term for summative purposes (termly exams). Assessment "for" learning integrated into the teaching and learning process for formative purposes is nascent. Despite this, this is at the centre of ESSP 2018-2024 and the new Competency-Based Curriculum iv. Attendance monitoring is paper-based and cumbersome to undertake, limiting how often it can be undertaken in a school day v. There are no mechanisms for students to provide feedback on teaching and learning quality or to evaluate their teacher's performance vi. No data link between teachers and students' learning outcomes (teacher-student link) vii. Lesson preparation and planning are largely solitary and not supported by technology	i. Schools have a customisable online learning delivery platform that supports remote access capabilities for both students and teachers. Teachers can simultaneously support class-sessions across multiple schools and students can document their progress using an e-portfolio of academic achievement ii. Capture data related to equity and access to education, especially for students with special needs iii. Teachers collaborate to design high-quality summative and formative assessments. Teaching and learning are routinely adjusted to cater for individual student need iv. Attendance monitoring for both teachers and students is automated and real-time, providing instant feedback to parents, teachers and the administration via a range of channels (e.g., SMS, email, chat, voice) v. Students have various ways to evaluate teaching and learning quality and provide feedback to teachers using digital tools vi. Teachers and students' data is linked to identify best practices and support scalable interventions based on longitudinal data that link student learning outcomes to

Transformation through integrated EMIS	Current state	Target State
	viii. Learning content is mainly physical and paper-based, limiting ways in which students can interact with it	multiple teachers, interventions, and schools over time vii. Teachers collaborate across the district/country to prepare lesson plans, sharing resources to handle subject content, and aligning assessments class lessons viii. Learning content is digitised in collaboration with teachers and curriculum experts, providing a variety of online learning options for students and different ways to interact with subject content that they are learning in class
Develop and empower teachers	i. Teachers have access to limited data about student performance, often garnered from their own physical interaction and observation from both inside and outside the classroom ii. Many teachers have insufficient competency in subject content, pedagogy and language of instruction (English) iii. Teachers do not provide all students with individual feedback on strengths and areas for improvement to progress learning iv. Many teachers lack the knowledge and skills to analyse student assessment data to identify learning gaps to meet the expected academic standards v. Most teachers cannot identify suitable focus areas for their own professional learning nor	i. Teachers have an extensive view of student data from a wide variety of sources to help understand how to support their students' learning process ii. Teachers have access to online collaboration tools, knowledge repositories and CPD courses to advance their experience and expertise iii. Teachers and students provide feedback to each other about student progress. Teachers leverage formative and summative assessment strategies, identify, articulate and explicitly teach the skills required for each student to improve iv. Teachers work in teams to analyse student assessment data and monitor learning outcomes as part of regular lesson planning

Transformation through integrated EMIS	Current state	Target State
	identify opportunities to build new knowledge and skills vi. Teachers often have to physically travel away from school to attend CPD training to build new knowledge and skills. The Government is implementing the School-based Mentorship Program aimed at conducting in-service training at the school level.	and review. They use this analysis to identify implications for future lesson planning including curriculum content and pedagogical approaches v. Teachers can evaluate the effectiveness of their practice, identify appropriate professional learning opportunities to build their knowledge and skills, trial new practices, monitor student learning and seek feedback from colleagues and students to gauge the impact of their changed practices
Improve Student Support	i. Most schools do not collect any health information for students beyond access to health insurance and student disabilities ii. Most schools do not collect any information on counselling and guidance given to students at school as well as any learning support that may be offered iii. Schools with a feeding program collect information on sponsors and parent participation. Some schools document the everyday meal offered to students on a given day. But not whether students consumed the meal iv. Schools collect basic information about sports, clubs and other extra-curricular activities found at the school, but not much information about actual student participation within such activities	i. Schools collect mandatory health information on students, including required immunisations, medications and encounters with school nurses. An examination report from a doctor is required for new students ii. Schools collect detailed counselling and guidance information related to process of change (*What was the process and who was involved?*) and perception or results emanating from the change (*What do people think they can do?*) iii. Schools collect extensive student feeding participation and nutrition information iv. Schools collect extensive data about students' involvement in different sports and extra-curricular activities to understand impact on student development v. Schools collect detailed discipline

Transformation through integrated EMIS	Current state	Target State
	v. Schools collect basic discipline information on student offences and disciplinary actions	information on student behavioural violations, both inclusionary and exclusionary disciplinary actions administered and their durations if applicable, other forms of discipline used to support student in meeting behavioural expectations as well as any individual circumstances or nature and circumstances of behavioural violation where applicable.
Improve School Administration	i. Schools do not capture data on head teacher management characteristics, leadership and their capacity as well as for school management committees ii. Student registration is largely paper-based with information and copies of collected documents stored as paper-records iii. Parents/guardians lack online access to information about their student's performance and behaviour at school iv. Regular communication with parents or the family is rare and is largely driven by adverse incidents like indiscipline or health issues v. Generating class and school timetables is a manual process, making it difficult to align different criteria (teachers, classrooms, curriculum,) that often change over time vi. Lots of school data collected can provide insight into internal efficiencies, user	i. Schools capture extensive data on school leadership and use this to determine leadership capacity development needs ii. Students and parents have direct access to student information and performance at school as well as general school information (timetables, events,) iii. Parents can receive automated updates about different student events like daily attendance via a range of communication channels iv. Teachers can easily communicate with parents and students using a wide variety of channels including email and messaging v. Generating class and school timetables for different periods is automated to accommodate available teachers and multiple designated criteria without conflicts vi. Student report cards are generated

Transformation through integrated EMIS	Current state	Target State
	interactions, and more. But it is silo-ed away in paper-documents, making it difficult to aggregate and provide a consolidated view that would be useful vii. Decisions are heavily influenced by historical data without support from predictive analytics that can provide insight into the future viii. It is difficult to anticipate the future population of children starting school and their distribution across the country to effectively allocate resources and build infrastructure in anticipation ix. Districts lack comprehensive data on school infrastructure like buildings, classrooms, laboratories, and equipment as they seek to fund, plan, construct and maintain these crucial elements of the learning environment x. It is difficult to gauge the impact of different teacher interventions on teaching practices, student outcomes and dropout rates, among other areas xi. It is easy to identify schools that are performing well in different parts of the country, but difficult to discern exactly they are doing well so that this can be replicated and scaled to achieve successes in other schools	automatically, contain both formative and summative evaluation of performance and can be accessed during the school term via a range of channels vii. Parents and students can pay various school dues using digital financial tools and receive automated confirmation viii. Stakeholders at different levels of the education sector make decisions based on data ix. Schools collect comprehensive data on school infrastructure, allowing districts to develop a long-term school infrastructure and facilities plan as well as budget for the costs associated of regular and incremental maintenance and upgrades x. Sector leadership and policy-makers can rely on predictive analytics to optimise the allocation of different resources to improve equitable access and the quality of education xi. REB and districts use student learning data for strategic planning of individual teachers and coordination of collective professional development

The gap analysis also highlights a number of other issues that include:

- Lack of formalisation of EMIS across the education sector,
- Limited number of dedicated staff working on EMIS solutions from both domain and technical perspectives across the education sector,
- Reliance on Commercial-Off-The-Shelf (COTS) software and services or ICT vendors due to limited capacity within institutions.

3.3.1 Metadata for Education

As discussed above, defining metadata (data about data) is an important issue to facilitate the integration of data across the education sector. Metadata management will help document the knowledge that some people "just know," so that everyone can be on the same page when they talk about data across the education sector.

Metadata provides structured information that describes, explains, locates and otherwise makes it easier to discover, retrieve, use or manage information. This lack of common data nomenclature means that:[2]

- A data attribute such as naming, field length, etc. relating to the same entity is different in various systems resulting in additional work when it comes to integration.
- A single data element may be entered inconsistently. For example, a late student may be entered as absent or late, depending on the meaning attached to being late in different schools.
- A single data value may be reported using different units. For example, one school may capture the dimensions of a classroom using metric units while another uses the English system.
- Multiple conflicting definitions, code sets, and calculations may be used, leading to different results by different institutions.
- A data item, or even an entire collection, maybe maintained when it no longer provides useful information.
- A new database may introduce terminology, definitions, and specifications that are not consistent with existing standards and protocols.

2 US National Forum for Education Statistics, Metadata for Education, Forum Guide to Metadata: The Meaning Behind Education Data https://nces.ed.gov/pubs2009/2009805.pdf

Metadata enables the definition of a common vocabulary at three levels—technical, data management and data use as highlighted in Table 8.

Table 8: Different levels of metadata

Technical	Data Management	Data Use
Field length	Meaning	Currency
Element type	Availability	Punctuality
Permitted values	Restrictions	Verification
Code set	Limitation	Validation
Translations	Components/operations	Identity
Storage/archival location	Purpose/rationale	Accuracy
Source	Owner	Reliability
Target	Steward	Completeness
Load time	Time parameters	Sparsity
	Treatment	Value set testing
	History	Coherence
	Retention	Continuity
	Security/Confidentiality	Contiguity

Source: US National Forum for Education Statistics

The use of metadata will be important in defining technical attributes such as field length that facilitate data management, improve understanding of business processes, reduce inconsistency and incorrect reporting, improve data comparability and continuity, improve data auditing and quality as well as data collection and use. Using metadata can also help to identify sensitive and confidential data, leading to improved systems security.

The development of metadata involves ongoing consultation on new metadata requirements and the adoption of existing education metadata. MINEDUC in collaboration with other sector stakeholders and NISR, will need to establish a Working Group on metadata drawn from different stakeholders across the education sector that encompasses different types of data users like statisticians, data managers and subject specialists. This Working Group will be responsible for:

- Identifying the common data to be used across the education sector and ensuring that a data dictionary and vocabulary is agreed on by all stakeholders.
- Assessing metadata needed for the education sector.
- Adoption and customisation of existing metadata.
- Establishing new metadata relevant to Rwandan educational environment,
- Undertaking capacity building.
- Defining the canonical data model that represents the common data entities identified in the previous step, their data attributes, the data types and the relationship between these data entities.
- Establishing data sharing services and defining the Service-Oriented Architecture (SOA) specification required to support the data sharing needs.
- Defining the education data XML schema for data sharing across the interoperability framework which will be based on the common data specification
- Establishing data sharing agreements. Evaluating policy changes at all appropriate levels of government that may be needed to support data sharing agreements.

- Addressing security and privacy issues that hinder data sharing.
- Formalising a data governance model and structure.

3.3.2 Governance and Coordination of an Integrated EMIS

The lack of education information governance is another major gap in the current education management information system. The implementation of an integrated EMIS is a complex and dynamic engagement in which key stakeholder involvement must be solicited during various project cycles. Coordination and leadership are important to develop policies, ensure data quality, security and confidentiality, resources mobilisation and change management as well as in promoting the sharing of information and resources.

It is therefore recommended that MINEDUC establishes a national Steering Committee that coordinates decision making on the development of an integrated EMIS. The Steering Committee, which can be chaired by the Permanent Secretary of MINEDUC and/or by the Director General of Education Policy and Planning, among others, would:

- Deliberate on policies and strategies for education data management and provide strategic direction and oversight of all data related activity in the education sector;
- Ensure consistency, collaboration, etc., as appropriate across inter-connected areas e.g. data, IT, information security, research, evaluation, reform;
- Make a decision on data collection, management and use including steps for maintenance of data quality;
- Define the roles and responsibilities of different stakeholders in the collection, management and use of education information system;
- Define data ownership, data stewardship, data management and data quality responsibilities;
- Determine the organisational hierarchy, culture, data and work flows from schools to MDAs and also back to the schools;
- Decide on capacity building and training requirements necessary to support this endeavour;
- Make recommendations on data privacy, confidentiality and security;
- Make change management plans to facilitate and sustain the enthusiastic acceptance and adoption of new strategies, technologies and processes in education data collection, processing and use among stakeholders, and
- Promote centralised technology architecture to mitigate data integration challenges between different agencies in order to meet the data and information needs of all education stakeholders.

3.3.3 Capacity Building Requirements

The alignment of information systems to the business processes, enterprise application integration and gradual implementation of enterprise architecture-led solutions requires ongoing training and capacity building for staff at MINEDUC and other MDAs. Highly skilled human resources are critical for the success of the implementation of integrated EMIS. Capacity building, which is central to developing the management and use of data, requires a systematic approach to the education and development of staff including headteachers, teachers and other stakeholders involved in data

collection, management and use. The aim will be to develop a mature level of "Data Literacy" among staff by providing training and support across a range of areas such as:

- Data management
- Data collection, processing, analysis and usage
- Data reporting requirements
- Data protection and security
- Knowledge management.

Besides, the government needs to develop a human resources policy that facilitates the attraction, career development and retention of those working in the areas of Information and Communication Technology (ICT) and Data Science/Statistics. Appropriate training should be provided on the basics of enterprise architecture and interoperability framework for non-technical personnel and advanced training for technical staff at MINEDUC, HEC, REB, RP, WDA and the University of Rwanda. The recommended course for managers and decision-makers should cover the introduction of enterprise architecture, benefits, the different architecture and interoperability layers and how these align with business objectives across the education sector.

The ICT professionals require more in-depth understanding of enterprise architecture and the interoperability framework. The following courses are recommended for ICT and technical personnel.

- Introduction to Enterprise Architecture, Interoperability
- Business, Application, Data and Infrastructure domains
- Integration with security architecture
- Enterprise architecture governance migration and change management
- Enterprise architecture tools and repositories
- Enterprise architecture modelling language (Archimate)
- Enterprise architecture maturity models
- Data literacy, statistical and data science methods and analytical tools

Further, technical personnel will need training in emerging Data Science, Big Data and Data Analytics technologies.

3.3.4 Organisational Framework for EMIS

MINEDUC is responsible for the overall education management system and relies on an in-house developed SDMS, which covers school management, student management, infrastructure management and education reporting modules. The application draws heavily on the data sheets that were designed by the EMIS unit within the Planning Department of the Ministry. The SDMS development and maintenance team, on the other hand is under the Corporate ICT department. While SDMS can provide the foundation for an integrated EMIS, the lack of an organisational framework means that systems will continue to proliferate on an ad-hoc basis with subject and data specialists relying on ICT departments for systems maintenance needs.

Apart from MINEDUC, which has a basic in-house development team, the rest of the institutions like REB, HEC, University of Rwanda, RP and WDA rely on external experts and the private sector for application development and maintenance. This raises a significant challenge for data privacy, confidentiality and security.

There is a need for a robust organisational framework for education data across Rwanda that is guided by an EMIS policy to establish a central EMIS unit at MINEDUC. The EMIS Unit needs to be positioned as a national point of reference for the collection, processing and dissemination of education data, potentially phasing out the various subsystems maintained by different agencies over time. The framework depicted in Figure 11 should also support decentralisation of EMIS activities to districts and schools in order to improve data collection and use at the local levels.

The EMIS Unit will be responsible for:

- Development of a comprehensive and integrated EMIS with the flexibility to allow districts and schools to manipulate and interpret and publish their own data,
- Liaison with other ministries and agencies to coordinate data collection and ensure data integration through integrated enterprise architecture and interoperability framework,
- Projections and ESSP Monitoring,
- Conducting internal data audits in order to spot anomalies and flag discrepancies,
- Provide technical support and training for districts and schools in data collection, management and analysis,
- Conduct ongoing information needs analysis to respond to users' data requirements proactively,
- Disseminate data in various formats including print and online format,
- Respond to queries from various users for data.

Based on these functions, the EMIS unit should have the following major teams:

- Technical support and training
- Data management, internal data audit and dissemination team
- EMIS development and improvement team

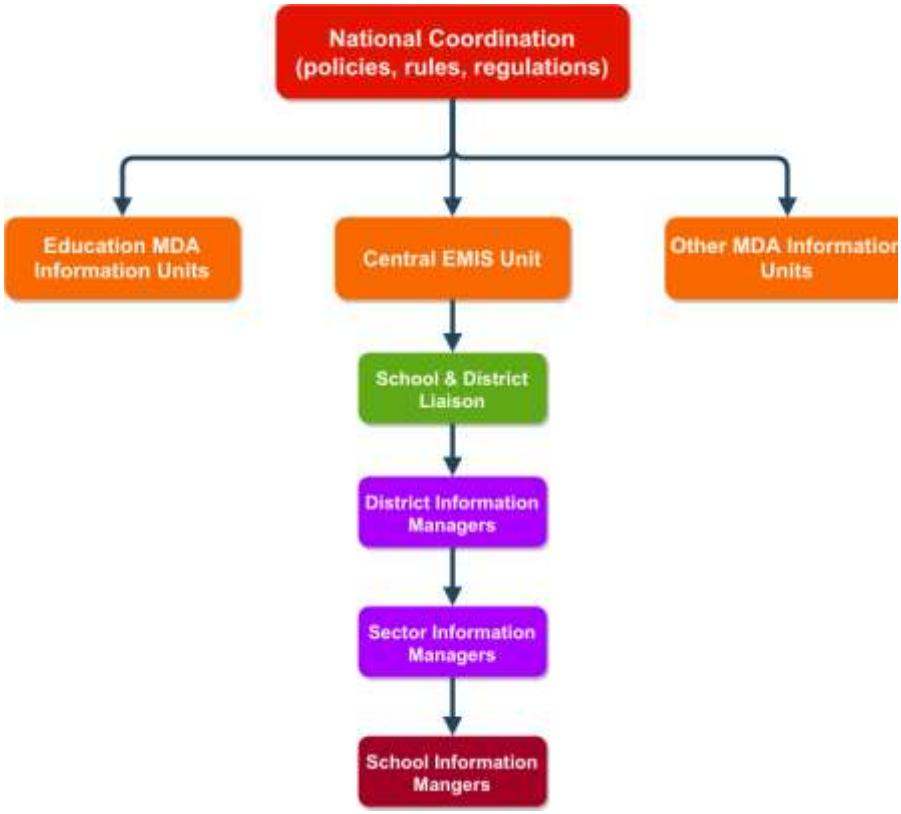


Figure 11: National organisational framework for EMIS

The proposed organisational structure of the unit is shown in Figure 12.

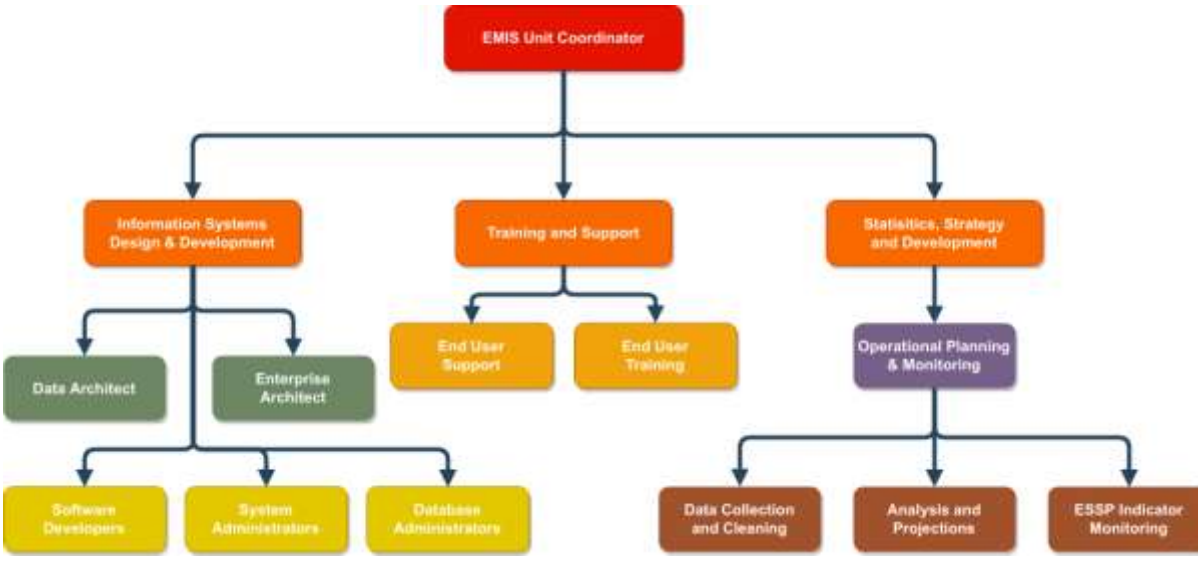


Figure 12: Proposed structure of EMIS unit

3.3.5 Adoption of Educational Interoperability

To create an integrated view of data across the education sector, MINEDUC needs develop interoperability between the different data management systems and digital content repositories. Interoperability in this case, will entail the ability to:

- Exchange academic and administrative data among systems and databases in order to be able to assess performance and/or support administrative reporting,
- Integrate education information systems with each other or with systems from other sectors to support different activities,
- Move digital content required for student learning and assessment to enable its integrated use in a wide variety of platforms.

To accomplish interoperability, the components that make up the different education information systems must adhere to similar standards for:

- Describing school, student and teacher data as well as digital content,
- Programming interfaces for systems and applications,
- Communication among different systems.

A complete standard includes a formal description of the structure of data and specific instructions for how that data is transported between different components of a network system and processed inside them. It accomplishes this by providing rules that address:

- Metadata—data about a set of data so that it can be recognised and used across different systems that subscribe to the standard in question,
- Transport protocols—procedures for establishing network connections between systems to enable data exchange,
- Interface rules—standard Application Programming Interfaces (APIs) that provide instructions for using common functions of a system.

There are a number of interoperability frameworks for the education sector, including those established through the School Interoperability Framework (SIF) Association, the Post-secondary Electronic Standards Council (PESC), and the Advanced Distributed Learning (ADL) Initiative.[3]

The SIF Association and PESC have produced the most widely adopted standards. These standard formats allow data from multiple sources (e.g., different schools or time periods) to be compared and allow data from one source to be shared across multiple systems or modules (e.g., attendance monitoring and assessment). The SIF data standard describes student data formats used by primary and secondary level systems, while the PESC data standards address tertiary level systems.

To integrate education information systems, there are the SIF Agent and SIF Zone Integration Server standards and the PESC Data Transport Standard and reference implementation while to move digital content across systems, there are education-specific content standards like the ADL's Sharable Courseware Object Reference Model (SCORM), Dublin Core Metadata and the IEEE Learning Object Metadata (LOM).

3 Advanced Distributed Learning Initiative https://www.adlnet.gov

Standards must be agreed upon, while taking into account education sector-specific issues like providing access and equitable learning opportunities to all students, including those with disabilities, data privacy and digital rights management, as well as controlling access and use through enforcing the appropriate policies.

To reap the benefits of interoperability, the education sector has to make some trade-offs, balance short-term vs. long-term or institutions vs. sector-wide goals. For example, stakeholders could agree that one can only build new systems if they clearly collect new data, target new sources, or their functionality cannot easily fit into existing systems. While this will be inconvenient in the short-term, it will help stakeholders to collaborate and work towards the sector's desired goal of an integrated EMIS.

3.3.6 Data Cleansing and Quality Control

As MINEDUC attempts to integrate data from various sources, a number of data anomalies will become evident, highlighting the need for data Quality Assurance (QA) processes to ensure consistency and standards. These may vary from missing fields (e.g. names, date of birth), wrong data (the national ID number given may be the student's or the parent's), out-of-date data ("ubudehe" category is entered one time at student registration and not updated when family status changes), and non-structured data (i.e. text fields).

This will provide an opportunity to talk about common data needs as well as data quality across the education sector. It can feature in the discussion to create a sector-wide data dictionary and schema agreed on by all stakeholders. Having established some data quality needs, the technical team can set up some automated tests of the data as it comes in from the source systems in an iterative manner. Also, the team will need to agree on methods to handle perceived data quality problems like data that fails one or more QA standards.

It is possible to "cleanse" data for integration by applying scripts to identify and rectify known issues in the data. Once the pertinent data elements are identified, data transformation and reformatting rules can be used to integrate data from the source system to the Data Warehouse. This may encompass methods to ensure data definitions are consistent across different data sources as well as data points within the same sources.

While the QA process can catch and flag issues with data, it cannot eliminate the issues from the source system; thus, data with issues will continue to be sent over again in future data feeds. This highlights the need for collaboration and feedback to the source system managers to continually improve data quality and to minimise data errors and omissions.

3.3.7 Data Security

Data security is currently addressed in each of the different information systems, but once data leaves these systems and is integrated with data from other sources, new privacy and confidentiality issues may arise calling for new protections. As part of the new EMIS policy, stakeholders will define who can access such integrated data and for what purposes. The data integration project team will conduct a full assessment of data security risks and how they can be addressed and managed. New security restrictions put in place should also comply with the security requirements of the Rwanda Government-wide Enterprise Architecture (RGEA).

3.3.8 National Student ID/Number

An integrated EMIS and other approved systems should use a universally unique identifier for students (and other people) that will make it easier for different stakeholders and systems to manage and share information about students in a way that protects their privacy. Activities to achieve this may include:

i. Working with stakeholders to come up with a unique number that should be assigned to every student
ii. Issuance of these numbers will be by the National Identification Agency (NIDA) via pre-primary education providers, schools or tertiary institutions where students first come into account with the education system
iii. Stakeholders can agree what purposes the number can be used for e.g. for enrolment and registration at a school
iv. The number should not be used for some things like school identity cards or as a primary key in a student database in order to protect student privacy
v. Information systems that manage any student information can use this number.

4. Towards an Integrated EMIS Architecture

The analysis in section 3 highlights that there are two broad challenges related to building an integrated Education Management Information System (EMIS). These are:

- The institutional and policy challenge—this must be addressed through foundational activities like creating an EMIS policy, establishing an EMIS governance and institutional framework and adhering to a common metadata framework as outlined above.
- The systems integration challenge—this must be addressed through adopting enterprise architecture principles as well as business, data, technology and application architecture proposed above.

The integrated EMIS will be based on a high-level education reference architecture presented in Figure 13 that conforms to the Rwanda Government Enterprise Architecture (RGEA) framework. This will result in a connected platform that brings together data from disparate sources and offers various services to different stakeholders, including those in other sectors but with a need for education data.

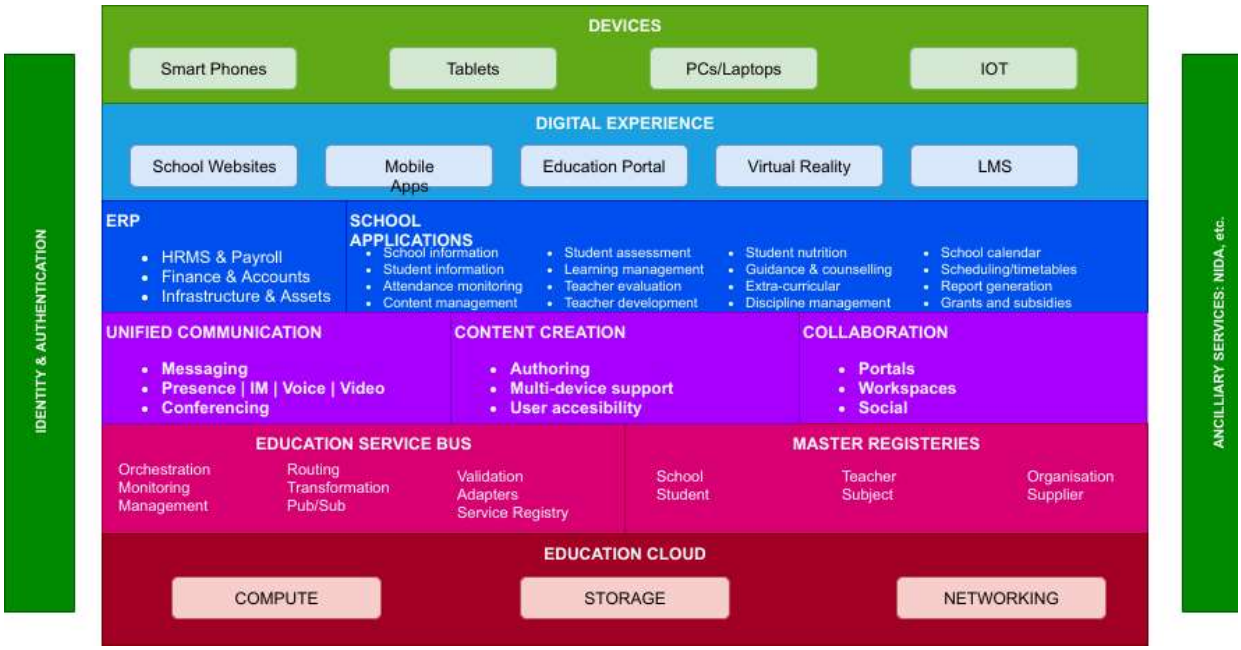


Figure 13: Reference Architecture for Education Sector

Given the RGEA's goal of improving service quality by promoting interoperability and reuse of standard components, this will make it easier to share and reuse other government data in real-time, helping to address the sector's overarching goals to improve overall access, quality and equity of education.

This will require some of the foundational activities like the adoption of unique identifiers for students and teachers, high speed internet connectivity across all schools, development of RGEA centralised services such as identity management and electronic payments as well as the use of advanced web and cloud technologies to connect and present data to different stakeholders

(teachers, students, parents, administrators, decision makers, etc.), in diverse formats, using a variety of different channels.

Data integration needs to begin as users capture data into the different information systems at the source. MINEDUC and other stakeholders need to create and enforce data entry standards, policies, validation and feedback mechanisms to improve data quality, reliability and applicability across the sector. In addition, stakeholders need to improve the data competence of staff responsible for capturing data in order to get clean data upfront to make subsequent steps of the integration process easier and more efficient. This is further discussed as part of developing the EMIS governance framework in section **Error! Reference source not found.**.

The end goal of our recommendation is the Reference Architecture for the Education Sector as illustrated in Figure 13. Taking into account that we are dealing with a production environment where the operations and activities supported by the current systems have to continue, we recommend a two-phase approach to achieving the end goal. This approach builds on the best existing systems while phasing out duplication, and then progressing to the realisation of the Reference Architecture. The recommended two-phase process to transition from the current state towards a fully integrated EMIS is detailed in Sections 4.1 and 4.3.

4.1 Phase 1

Phase 1 will involve the upgrading of SDMS and TMIS as building blocks for an integrated EMIS with linkage to post-secondary education systems, including TVET-MIS and UR's Integrated Electronic Business Management Information System (IEBMIS) via a Data Services Bus. This will help drive digital transformation to improve access, quality and equity of education by leveraging technology and data in four key areas, namely—teaching and learning processes, professional development and empowerment of teachers, student support services and school administration. SDMS and TMIS are selected as a foundation because the two systems contain key student, teachers and asset registries of critical data that underpins operations across the four key areas above. SDMS has the most comprehensive data on schools, students and the curriculum while TMIS has the most comprehensive data on teachers. Table 7 summarises current and target states for each of these four key areas.

Figure 14 shows a schematic diagram of the integrated EMIS to be developed in phase 1 over the next two years by building on the foundations of the upgraded SDMS and TMIS.

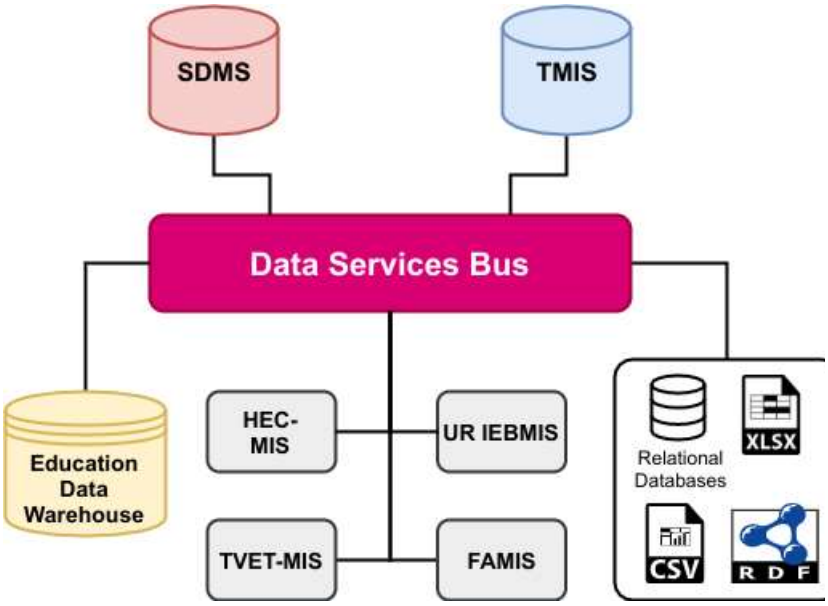


Figure 14: Integrated EMIS in Phase 1

The Data Services Bus will provide the foundation for service-oriented architecture development efforts by providing a platform to integrate data from various existing information systems summarised in Table 9 into an integrated Education Data Warehouse (EDW) to create a "single source of truth" in terms of data for the whole education sector.

Table 9: Core systems for Education Data Warehouse

System	Data Provided
School Data Management System (SDMS)	Authoritative source for school and student information as well as some curriculum information. This should become the primary interface for schools to submit different kinds of data required by different stakeholders.
Teachers Management Information System (TMIS)	Authoritative source for teacher information. This should become the primary interface for managing teachers both at the district and REB levels.
Learning and Teaching Materials Management System (LTMMIS)	Includes aggregate data that already exists in other systems. This data can be extracted from existing systems without the need for schools to input data. As the sector moves towards digital learning resources, this system can be phased out completely. The school inspection/school performance monitoring module is powered by data collection forms that can be replicated in other data collection systems with prior data pre-loaded from existing systems
Formative Assessment Management Information System (FAMIS)	Supports formative assessment of student learning using standard tests. The system should get student data from SDMS and teacher data from TMIS. The system will provide data on student performance in formative assessments.
National Examinations Publication System (NEPS)	Authoritative source for student assessment for final examinations for P6, S3 and S6. The system functionality will be subsumed into SDMS, where authoritative data already exists on students, schools and subjects of

System	Data Provided
	examination. This system will be phased out immediately.
TVET-MIS	Authoritative source for TVET student admission information, registration as well as assessment and progression. The system also captures basic information on tutors, school infrastructure and the curricula across Integrated Polytechnic Regional Centres (IPRCs)
UR IEBMIS	University of Rwanda's integrated MIS from Adapt IT in South Africa that supports a students' life-cycle at the university and other business processes like human resource and finance management

This phase will include the following activities:

- Upgrading SDMS to cater for all the necessary modules (as discussed in section **Error! R eference source not found.**) to meet the data requirements for pre-primary, primary and secondary education and adult learning.
- Upgrading TMIS to cover both teacher administrative components (i.e, registration and management) and professional development components (i.e., practice, evaluation, and training).
- Data integration of UR IEBMIS, TVET-MIS, HEC-MIS and other external data sources through a Data Services Bus with the transformed data loaded into an Education Data Warehouse.
- Building analytical and query tools to create data view dashboards for different stakeholders interested in education data.
- Ensuring that the systems are built with open standards so that they align with the Rwanda Government Enterprise Architecture (RGEA).

4.1.1 Upgrading SDMS

Figure 15 shows a conceptual design of an improved SDMS showing various modules that capture data on schools, students, student-level activities, infrastructure and assets among other aspects. The modules in green do exist and are well-developed, the modules in yellow do exist, but are still basic while the modules in red need to be developed.

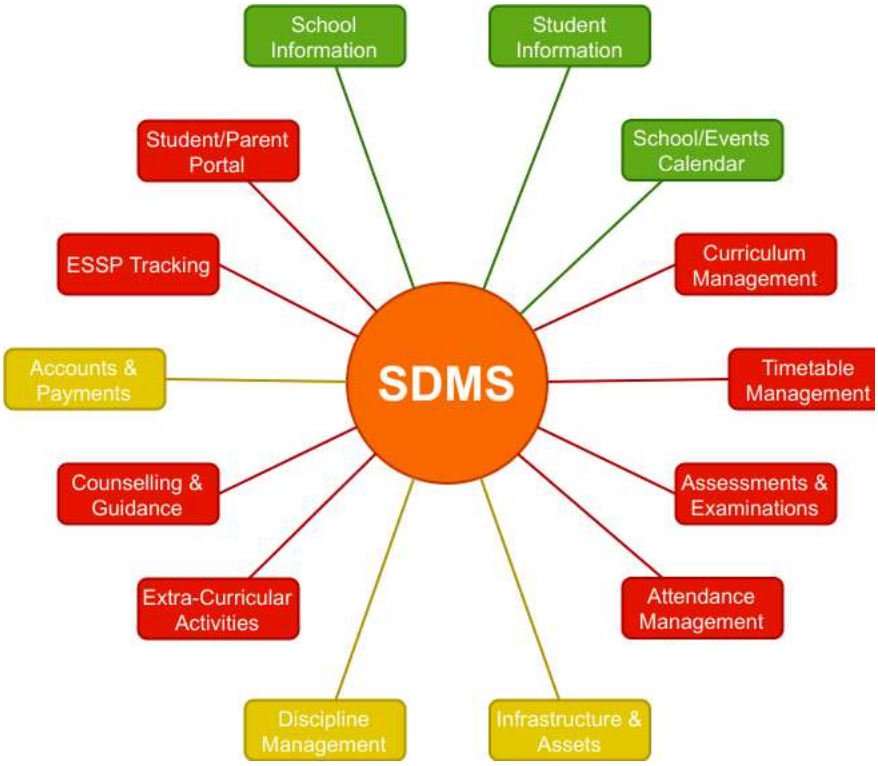


Figure 15: SDMS modules

The upgrading of SDMS will require increasing the human resource base and building up the technical capacity of the MINEDUC ICT unit to redesign the application, integrate existing modules and develop new ones and to support users across the country. This will require buy-in from all organisations involved in early and basic education data management as well as adequate financing.

Some of the actions required to redevelop the SDMS as part of a fully integrated information system include:

- Agree on metadata and data dictionary for the education sector and refine data fields accordingly
- Agree on all the modules that meet the needs of the education sector.
- Integrate existing and develop new modules to address needs across the sector. Figure 15 highlights potential modules include:
  - Attendance monitoring for both students and staff,
  - Student feeding and nutrition,
  - Student discipline management
  - Student counselling and guidance
  - Teacher management and career development
  - School curriculum management
  - School inspection
  - School infrastructure and asset management incorporating both maintenance and future planning
- Add functionality to help improve school operations, some of which are already under consideration include:

- Online school fees payment (pipeline)
- Student academic report preparation (pipeline)
- Communication with parents and teachers (for example, send an SMS to a parent whose child is absent from school with no prior explanation after student attendance has been recorded in class)
- School/class timetabling, along with assigning teacher subjects based on their competence (for example, the Head Teacher or Dean of Studies can generate school timetable based on curriculum, student registration and teacher data)
- Learning resources management including text books, open educational resources, and laboratory/library management
- Tracking ESSP indicators
- Document management.

The redeveloped SDMS can also be used for monitoring progress with the implementation of the education sector plan, providing a comprehensive understanding of education sector performance. This proposal is in line with similar integrated education management systems that provide data on basic education, but also link to tertiary education Enterprise Resource Planning (ERP) system.

For teaching and learning processes, SDMS and TMIS need to capture key information that relates to the curriculum, student and teacher attendance, different types of student assessment as well as detailed information that relates to student health, feeding & nutrition, counselling & guidance, discipline & behaviour, sports & extra-curricular activities, all of which have potential impact on student development. With such detailed information, SDMS can then offer tools to automate tedious tasks like generating school and class timetables as well as student reports, which consume a lot of administrative resources.

For student assessment, SDMS needs to capture data beyond summative assessments that normally comprise termly and end of year examinations to include formative assessments like Early Grade Reading Assessment (EGRA), and Early Grade Mathematics Assessment (EGMA). Assessment should also encompass classroom work to help students clearly understand where they are in terms of knowledge, where they need to get and how to bridge the gap, as presented in Figure 16.

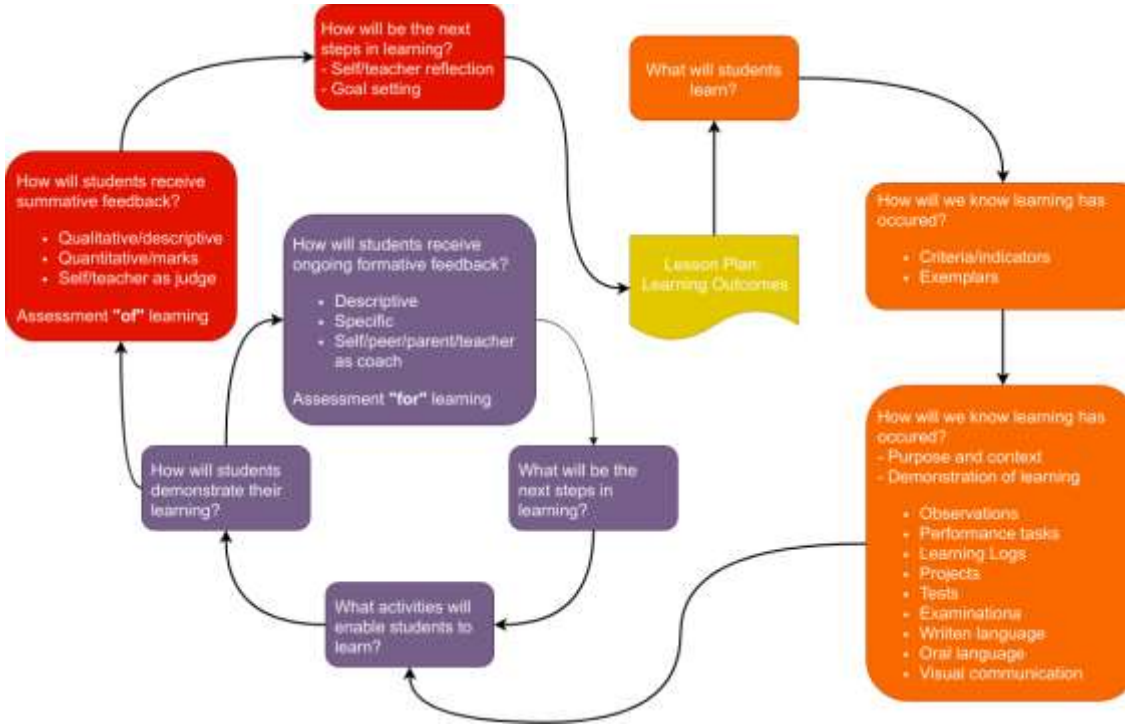


Figure 16: Assessing, evaluating and communicating student learning in the classroom

Further, SDMS needs to capture more detailed data on school infrastructure and assets to facilitate schools to plan for routine repairs and maintenance to improve cleanliness, orderliness, and safety. Based on the data, districts need to develop long-term maintenance and development plans as well as budget for associated costs that may encompass providing new infrastructure and facilities or even constructing new schools all together to address growing demand for education in their jurisdiction.

4.1.2 Upgrading TMIS

While ESSP places great emphasis on teacher professional development and management, current practice does not clearly identify highly effective teachers to understand how they excel and to retain, promote, or place them in assignments that maximise the impact that they can have on student learning. There is also a similar tendency to neglect identifying under-performers. As REB and other stakeholders work to improve TMIS, the importance of linking teachers' and students' longitudinal data to identify best practices and support scalable interventions that link student learning outcomes to multiple teachers, interventions and schools over time should take centre stage.

Figure 17 indicates the major steps in a teacher's career growth within a school and/or district. TMIS currently places more emphasis on teacher administrative components in orange (registration and management) as compared to teacher professional development components in green (practice, evaluation, and training). Most teachers need support identify suitable focus areas for their own professional learning and to identify opportunities to build new knowledge and skills.

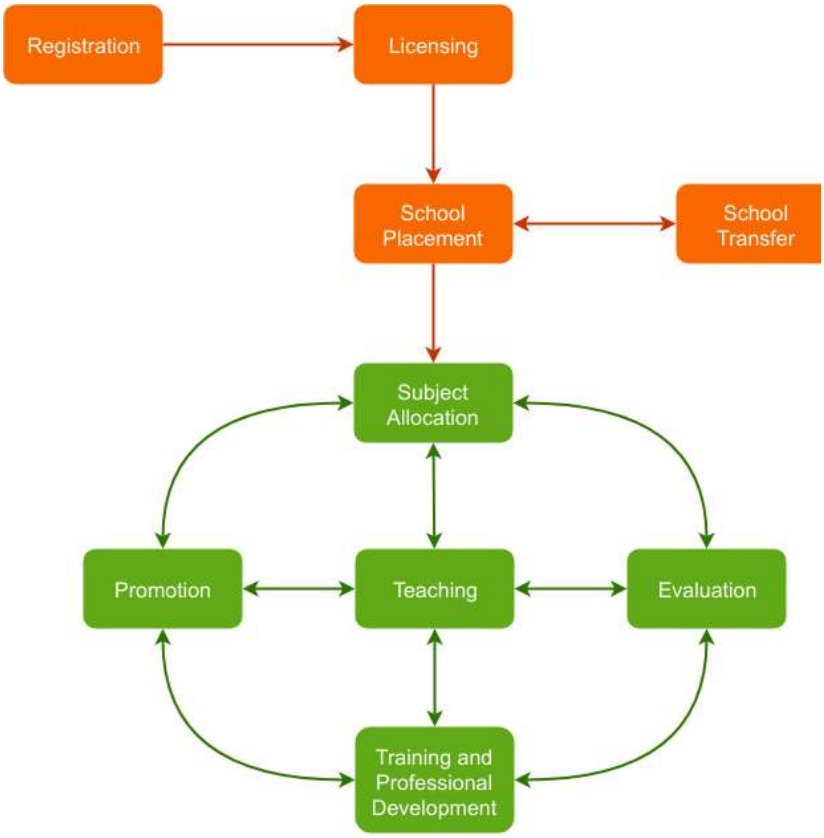


Figure 17: Teacher's career cycle

Teacher professional development practice needs to offer alternative developmental paths for individual teachers based on their needs or weaknesses. To achieve this, districts and REB need multiple forms of evidence to evaluate teachers better. There is an on-going policy debate across the sector about the need to redefine teacher quality and how this can be used to assess teacher performance. A teacher's evaluation should be based on student achievement, as well as other measures as highlighted in Figure 18. This will help to identify both the more effective teachers for promotion, and the less effective teachers in need of support, helping to ensure that all teachers have the appropriate level of skills and competencies to deliver the Competence-Based Curriculum (CBC) successfully.

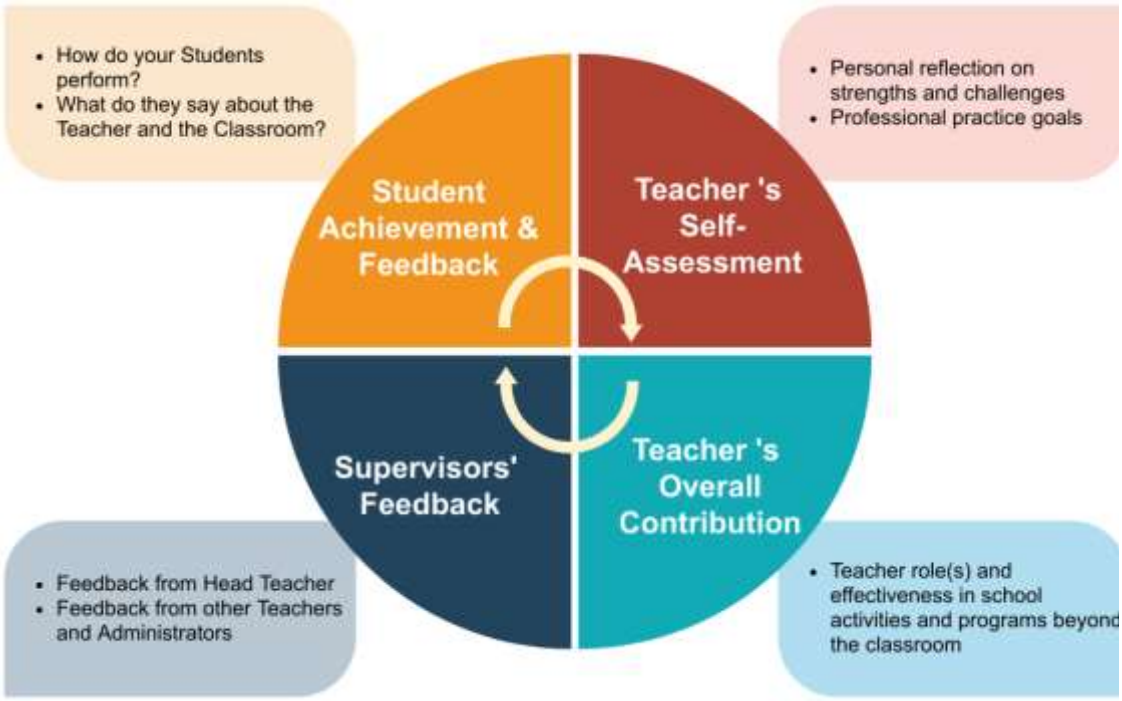


Figure 18: Measures contributing to teacher evaluation

As REB and district officials use TMIS to recruit and better manage teachers for basic education, TMIS needs to collect more data on teacher evaluation including teacher self-reflection and goal setting, teacher artefacts like lesson plans, teacher contribution to student achievement, student/parent perception surveys, periodic observations of classroom teaching and feedback from peer and supervisors. Evaluation should be both formative, allowing teachers to adjust goals and plans during the year, and summative, to determine final ratings, resulting in actionable feedback that influences professional development and training as well as connection to resources, support and opportunities.

4.1.3 Building Data Services Bus and Data Warehouse

The Data Services Bus will provide a platform to integrate various data sources, create composite data views and in future (phase 2), host data services that make integrated data available as a service, for easier reuse and to allow other external systems to interact with education data easily. It will incorporate Extract, Transform and Load (ETL) features to:

- **E**xtract data from multiple source systems and other external sources
- **T**ransform data in different formats to a unified form expected by the Education Data Warehouse
- **L**oad or store the transformed data in the Education Data Warehouse.

Figure 19 shows the architecture of an Education Data Warehouse (EDW) that will create a "single source of truth" for education sector-wide data by integrating data from different systems summarised in Table 9 including the upgraded SDMS and TMIS.

The Data Service Bus needs to support, secure and manage data access, data transformation and validation and the ability to combine data from multiple sources in a single query or support nest queries across multiple data sources. Some of the key features to take into consideration in building

the Data Bus include:

- Ability to expose any data store as a web service or REST resource (JSON, XML)
- Support for a wide range of data sources (e.g., RDBMS, CSV, Excel, ODS, RDF, Google Spreadsheets)
- Support for a wide range of databases (e.g., MySQL, PostgreSQL, MSSQL, Oracle, or any database with a JDBC driver)
- Support for a wide range of transport protocols (e.g., HTTP, HTTPS, JMS, SMTP, FTP, FTPS, SFTP, TCP and OData)
- Ability to transform and validate data (XSLT, Xquery)
- Ability to combine data from multiple data sources in single response and to support nested queries across data sources
- Comprehensive management & monitoring web console.

Data sources may contain structured data (e.g., relational databases, Excel spreadsheets, etc), unstructured (e.g., Word documents, text files, flat files, etc), or big data repositories (e.g., IOT sensor readings records) as indicated in Figure 19. In the Data Services Bus, there is an Integration Area, where data from the disparate sources will be linked, transformed and structured in a suitable format before being stored in the EDW. In the EDW, In the Storage Area, persistent data from across the sector will also be stored. Except for the Operational Reporting Data Repository, the other repositories in this area grow constantly, new data is added but no old data is deleted, this area contains education sector-wide memory to enable stakeholders to determine data trends. The Presentation Layer will be composed of tools used to obtain insight from the data stored in the Storage Area of the EDW from simple reporting tools to complex data mining tools.

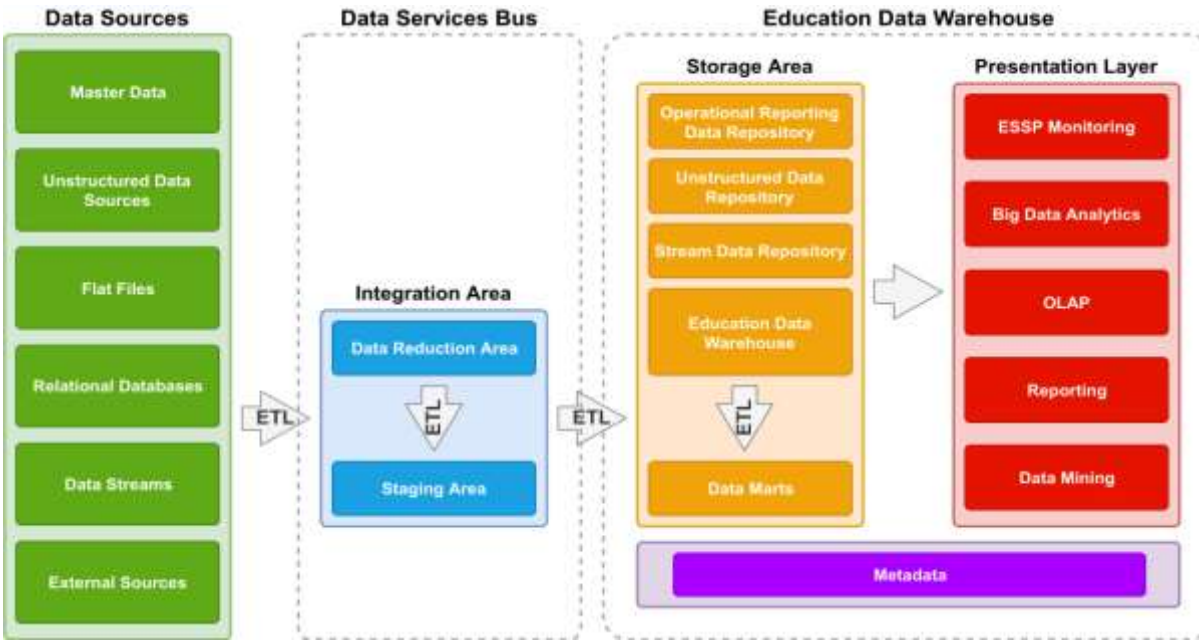


Figure 19: Education Data Warehouse Architecture

Data will be transferred from each source system as periodic batch jobs using agreed protocols (e.g., sftp, ftp, smb, email, https) and encryption standards as presented in Table 10. The schedule of data

updates or how often data should be refreshed will vary depending on how often various systems get updated. For example, school users will interact with SDMS more often because it touches on student life, while teachers may interact with FAMIS a couple of times during the term. All data loading will happen during the night, when system usage is minimal.

Table 10: Data source systems and connection methods

System	Remote Server	Connection	Schedule
School Data Management System (SDMS)	IP address: 197.243.48.5 Linux	Direct Connection to PostgreSQL database via JDBC	Weekly, (weekend, night)
Teachers Management Information System (TMIS)	IP address: 197.243.16.105 Linux	Direct Connection to MySQL database via ODBC	Weekly, (weekend, night)
Learning and Teaching Materials Management System (LTMMIS)	IP address: 41.74.172.64 Windows Server	Direct Connection to Microsoft SQL database via ODBC	Monthly, (weekend, night)
Formative Assessment Management Information System (FAMIS)	IP address: 197.243.16.103 Linux	Direct Connection to MySQL database via ODBC	Monthly, (weekend, night)
National Examinations Publication System (NEPS)	IP address: 41.74.172.64 Windows Server	Flat file in CSV format	New results available

We can extract a subset of the data from the EDW and build a data mart to address the needs of a specific stakeholder (e.g. MINEDUC or REB), a specific business function or to create an authoritative register (e.g. for students or schools). Providing different stakeholders with a subset of the data from the EDW can enhance performance by reducing the volume of data and providing access to a stakeholder's frequently used data as well as improve privacy by providing only access to a subset of sector-wide data that addresses the needs of a specific stakeholder.

4.1.4 Phase 1 Main Cost Elements

The main cost elements of Phase 1 will include:

- Technical advice/support on databases management and integration: USD350,000
- Upgrades to SDMS and TMIS, Data Services Bus and EDW platforms: USD325,000
- Staff training and capacity building for EMIS Unit staff: USD150,000
- Storage and compute costs at national data centre: USD75,000.

Please note that this does not include the cost of other foundational roadmap activities such as an EMIS policy or the organisational and governance framework, discussed in section 5 that have to be implemented regardless.

4.2 Transitioning to Phase 2

In order to be successful during this phase and to minimise the proliferation of duplicate systems, we recommend a number of principles that should be discussed and agreed upon by all sector

stakeholders. These will include:

i. SDMS will be the primary interface through which schools provide any data that is required by all stakeholders across the education sector. SDMS will also be the authoritative source for school and student information as well as some curriculum information that underpins some of the registries in the EDW.
ii. TMIS will be the primary interface for recruiting and managing teachers at both district and REB levels. TMIS will also be the authoritative source for teacher information that underpins some of the registries in the EDW.
iii. NEPS functionality can be subsumed into SDMS where authoritative data exists on schools, students and different subjects that make up the curriculum. SDMS assessment functionality will be extended to directly capture student marks and grade for transition-level exams like P6, S3 and S6 as well as each student's unique index or examination number. REB and MINEDUC can provide user access to a subset of examination results via a variety of channels from the EDW.
iv. LTMMIS includes aggregate data that already exists in SDMS and TMIS. This data can be extracted from the EDW without the need for schools to directly input any data. As the sector moves towards digital learning resources, this system can be phased out over time. The school inspection/school performance monitoring module is powered by data collection forms that can be replicated in other data collection systems with prior authoritative data pre-loaded from the EDW.
v. FAMIS supports formative assessment of student learning using standard tests. The system can use authoritative student, teacher and subject assembled in the registries in the EDW. FAMIS can continue to host the unique data composed of question banks prepared by teachers and experts to assess student proficiency in different subjects. When students complete formative assessment assignments, FAMIS can send this data to individual student profiles in SDMS.
vi. Before building any new information systems, stakeholders will first consider extending current systems. They will only build new systems if they clearly collect new data, target new data sources, or the new functionality cannot easily fit into existing systems.

There are a number of accomplishments that will signal improved maturity and collaboration among sector stakeholders and facilitate the transition from phase 1 to phase 2. Key among these will include:

i. Implementing an EMIS policy that clarifies stakeholder roles and responsibilities across the data value-chain amongst other things.
ii. Agreeing education metadata and data dictionary that is recognised and used by different stakeholders in their data activities across the sector.
iii. A Data Services Bus to integrate data from multiple selected systems and an Education Data Warehouse (EDW) platform that provides some mechanisms to visualise and interact with the aggregated data (analysis, dashboards, reports and visualisations).
iv. Dedicated EMIS Unit at MINEDUC that is able to maintain the EDW and uses it as a means to integrate disparate data from across the education sector and beyond.
v. Basic interoperability standards that encompass both technical issues (see section **Error! R**

eference source not found.) and policy issues (see section **Error! Reference source not found.**) that govern the seamless and secure exchange of education data across the sector.

4.3 Phase 2

Phase 2 depicted in Figure 20 provides the ultimate integration of educational administrative data to learning resources information to monitor learning outcome in near real-time, with a full linkage to other public sector data through the Government Service Bus. The transition between phase 1 and 2 is seamless. Phase 2 builds on the successful implementation of activities from phase 1 (see section **Error! Reference source not found.** and **Error! Reference source not found.**), and assumes an en vironment that includes:

- Full school connectivity in order to access and provide data through an education cloud environment,
- Developed RGEA centralised services such as identity management and electronic payments that can be used to power government-wide online services.
- Seamless data sharing as well as applications and services reuse between educational entities.

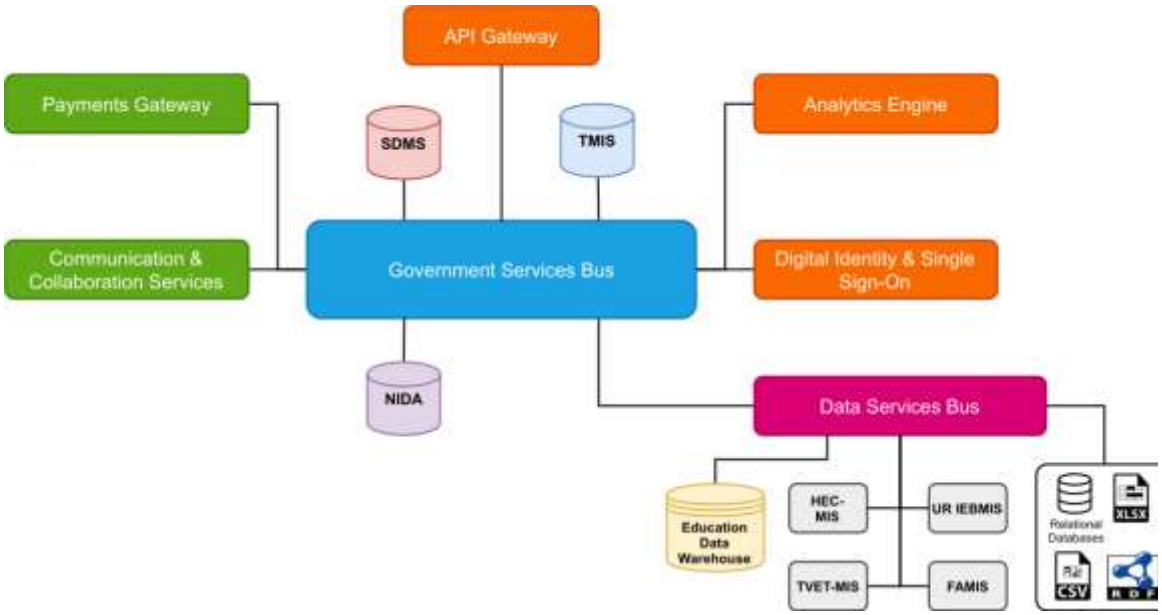


Figure 20: An Integration Framework for Education Sector

The different components of an integrated EMIS based on the RGEA and education reference architecture are briefly detailed in the sections that follow.

4.3.1 Government Enterprise Service Bus

The Government Enterprise Service Bus (GESB) is one of the main pillars of the national infrastructure developed and managed by RISA. Currently in pilot, the GESB provides a service layer that contains rules and a common framework that allows multiple systems from different government MDAs to

communicate with each other and exchange data for timely delivery of government services. The GESB aims to interconnect back-office systems using a single point of connection, eliminate duplication of resources and security gaps in data exchange, and harmonize interconnection protocols, policies and procedures. Various systems from institutions such as the Ministry of Local Government (MINALOC), Ministry of Finance and Economic Planning (MINECOFIN), National Identification Agency (NIDA), Rwanda Revenue Authority (RRA), Rwanda Development Board (RDB), Rwanda Natural Resources Authority (RNRA), Rwanda Utilities Regulatory Authority (RURA), and the National Bank of Rwanda (BNR), are being interconnected through the Enterprise Service Bus. Eventually, the EMIS need to be linked to the Rwanda Government Enterprise Service Bus to ensure data exchange and sharing. The GESB and the Data Service Bus will facilitate a solution that provide education data as a service (or as query-able OData endpoint) where it is needed to facilitate government business functions in a timely and protected manner.

4.3.2 Digital Identity and Security

Digital Identity and Security is another component of the RGEA security and authentication framework that will be implemented during this phase to connect systems operating with disparate security protocols to provide and consume identity services. It will have the capacity to provision a large number of users whose roles and privileges change over time based on the education calendar and cycle. To support the complexity of changing user roles and privileges, the architecture will allow other services and applications to connect with a centralised policy engine that can validate user access entitlements, eliminating the need to maintain individual application access policies and provide a consistent environment when authorising user actions. Users will have the ability to use the same account across all systems or do Single Sign-On (SSO). In addition, users will have the ability to select and perform various multi-factor authentication mechanisms.

Some of the key features to take into consideration in building security and authentication include:

- Ability to manage users and groups, rule-based identity provisioning, user profiles, recaptcha, and configurable password policies
- Support for SSO (e.g., SAML2, OpenID Connect) and federation with external identity providers
- Support for strong authentication (e.g., MFA, multi-option/multi-step)
- Support for role-based access control (RBAC), digital certificates and keys
- Complete SOAP API to integrate or embed into new applications or services
- Support for plug-in model for user stores, authenticators, OAuth2 grant types, etc.
- Ability to log, monitor and audit different types of events (e.g, login, password changes, session monitoring).

4.3.3 Analytics Engine

The Analytics Engine will provide big data analytics and real-time event processing capabilities for the integrated EMIS to provide relevant and personalised insight into valuable sector-wide data. With both batch processing and real time processing capabilities, the analytics framework should be able to identify trends and patterns to enable education policy-makers and administrators to be more proactive when making decisions.

The platform should enable users to define business rule templates and to generate business rules

for different scenarios as well as customisable dashboards that enable users to visualise analysis results according to their changing requirements.

Some of the key features to take into consideration in building an analytics engine include:

- Support for different data store connectors (e.g., RDBMS, MongoDB, Cassandra, Solr, and Redis)
- Support for different event sources and event sinks (e.g., HTTP, TCP, NATS, Kafka, CDC, JMS, MQTT, Email, File) as well as different data formats (e.g., JSON, XML, CSV, and Text)
- Support for streaming and complex event processing constructs (e.g., filters, patterns, non-occurrence, streaming aggregations, anomaly detection)
- Support for trigger alerts and notifications
- Support for machine learning and machine learning models
- Includes Graphical User Interfaces that enable users to create business rules and dynamically deploy them
- Ability to generate widgets that can be used to build user analytics and visualisations.

4.3.4 Communications and Collaboration

The Communications and Collaboration component will allow people, systems, and devices to communicate asynchronously. Given the large number of users, different types of devices and connectivity options (e.g. many users will connect from rural areas have challenges with Internet connectivity), it is important to have the ability to support large numbers of subscribers, queues and messages as well as provide guaranteed delivery of messages. The architecture will support message exchange patterns like pub/sub, message queues as well as lightweight protocols, such as MQ Telemetry Transport (MQTT) to address the growing importance of mobile and Internet of Things (IoT) devices in Rwanda's developing country context.

Some of the key features to take into consideration in building communication and messaging include:

- Support for MQTT protocol, and different quality of service levels
- Support for Java Message Service (JMS) standard v1.0 and v1.1 API
- Support for Advanced Message Queuing Protocol (AMQP), a leading industry standard protocol for interoperable reliable messaging
- Support for relational databases as a scalable backend message stores
- Support for distributed queues (e.g., subscribers, publishers,), in-order message delivery, and strict and best effort (faster) delivery guarantees
- Comprehensive management and monitoring web console.

4.3.5 API Gateway

The API Gateway will provide managed and secure access to APIs across the integrated EMIS by allowing potential application developers to search, browse, and locate APIs that meet desired functionality, improving data reuse. It will provide API management functions like wizards to automate provision of an API, provide feedback on API usage and collect feedback from API users.

Some of the key features to take into consideration while building the Education API Gateway

include:

- Support for publishing APIs for different stakeholders (e.g., internal users, external consumers) and easy management of API life cycle
- Support for publishing REST, SOAP, JSON, and XML style services as APIs
- Ability to provision API keys and manage API subscriptions on per-application or service basis
- Ability to control API access (e.g., OAuth, Basic Auth, API Key, Mutual TLS, OIDC) and enforce different security policies
- Ability to publish API usage to pluggable analytics framework (e.g., subscriptions, requests, responses, faults, throttling, self-sign ups)
- Support for role-based access control to manage users and their different authorisation levels
- Support for threat detection and protection (e.g., from bots and fraud) as well as detection of abnormal system use through artificial intelligence and machine learning.

4.3.6 Education Cloud

The Education Cloud will be Hosted at the National Data Centre and provide a solid hosting platform combined with an efficient framework and a set of tools to the allow for the rapid creation of new education services. It will adopt a microservice approach to allow stakeholders to cut down the time it takes to create and deploy new services. The granularity of a microservice architecture allows different stakeholders to build solutions in an agile approach while the loose coupling of services will empower stakeholders the ability to make modifications and improvements without fear of impacting other services.

Some of the key features to take into consideration while building the Education Cloud include:

- Ability to host and manage web applications and services (e.g., SOAP, JAX-WS, HTTP/JSON, JAX-RS)
- Support for different container-based environments (e.g., Docker)
- Support for development, debugging and deployment of applications and services with tools for message tracing and interactive testing
- Support for integrated security management for applications and services (e.g., SAML2, OpenID, LDAP, Google Auth)
- Provide APIs that encapsulate complexities of security, data management, metadata management, etc.
- Support for cloud-enabled, shared, self-service, multi-tenant applications and services that can elastically scale
- Comprehensive management and monitoring web console.

4.3.7 Other Desirable Components

There are a number of other desirable components that will enhance the operations

i. A Payments Gateway to facilitate payments for government services through support for a wide range of payment channels and Payment Services Providers (PSP).
ii. An Application Gateway to provide the ability for stakeholders to register and make specially

developed applications (mobile, web, or desktop) or those bought from elsewhere available to different users (e.g., students and teachers) across the education sector. It will help to organise the different applications, allowing administrators to be able to restrict access and monitor application usage on one hand, while enabling users to easily discover and self-subscribe to an application that they are looking for via a web-based application store that is also accessible on mobile devices. Users should also be able to use single sign-on across applications that they are registered for, eliminating the need to have multiple passwords.

4.3.8 Phase 2 Main Cost Elements

The main cost elements of Phase 2 will include:

- Two-year technical advice/support on implementing SOA reference architecture and integration: USD200,000
- Additional technical expertise: USD150,000
- Development, software platforms and tools, support: USD500,000
- Staff training and capacity building: USD150,000
- Storage and compute costs at national data centre: USD100,000.

Please note that this does not include the cost of other foundational roadmap activities discussed in section 5 that have to be implemented regardless.

4.4 Summary of Costs

Table 11 provides a direct comparison between the two phases.

Table 11: Comparison of the different phases

Category	Phase 1	Phase 2
Technical requirements	Data Services Bus for data Integration and tools for developing new educational data modules. Commercial or open source ETL tools like Apatar, CloverETL, Pentaho and Talend.	Rwanda Education Cloud that provides service hosting and frameworks Government Service Bus (by RISA) API Gateway Communications and Collaboration Analytics Engine Security and Authentication Bus
Human resources requirement	Additional staff at EMIS Unit Additional technical expertise	Additional staff at EMIS Unit Additional technical expertise Lots of other technical team members that work a scaled agile framework
Cost elements and cost estimate	• Technical advice/support on databases management and integration: USD350,000 • Upgrades to SDMS and TMIS, Data Services Bus and EDW platforms: USD325,000 • Staff training and capacity building:	• Technical advice/support on implementing SOA reference architecture and integration: USD350,000 • Development, software platforms and tools, support: USD500,000 • Staff training and capacity building:

Category	Phase 1	Phase 2
	USD150,000 • Storage and compute costs at national data centre: USD75,000 Total cost estimate: USD350,000 + USD325,000 + USD150,000 + USD75,000 = USD900,000	USD150,000 • Storage and compute costs at national data centre: USD100,000 Total cost estimate: USD350,000 + USD500,000 + USD150,000 + USD100,000 = USD1,100,000
Implementation timeline	2020-2022	2023-2025

5. Road Map and Implementation Plan

Based on the preceding analysis, the implementation of an integrated EMIS will require the following:

i. Core enterprise architecture principles are agreed on and adhered to,
ii. A data integration option is selected and approved,
iii. Policies, rules and procedures are developed and implemented,
iv. Organisational and governance framework are established,
v. Pragmatic strategies for improving data standards and attaining full data integration (e.g., defining metadata are put in place)
vi. Potential areas for application integration and new systems are identified and pursued,
vii. Resources that are required to move to new policies, procedures, organisational framework, data standards and solutions are mobilised.

This implies that MINEDUC and stakeholders need to embark on a series of projects that enable the implementation of an integrated EMIS. These will include:

i. Developing an EMIS policy to support the implementation of EMIS in Rwanda.
ii. Establishing a Governance and Coordination Framework for an integrated EMIS.
iii. Establishing a dedicated EMIS Unit at MINEDUC with support structures at other levels.
iv. Development and adaptation of metadata and standards.
v. Defining interoperability requirements that new school systems need to comply with to meet minimum standards.
vi. Establishing an integrated EMIS and subsystems.
vii. Building the skills of EMIS stakeholders at different levels: national, district and school.

Figure 21 shows an implementation timeline for the different projects, while section 5.8 provides cost estimates for the different projects.

Depending on whether or not government has the necessary in-house expertise, some of these projects may require the support of external consultants. Should that prove necessary, capacity building should be a major element of the terms of reference.

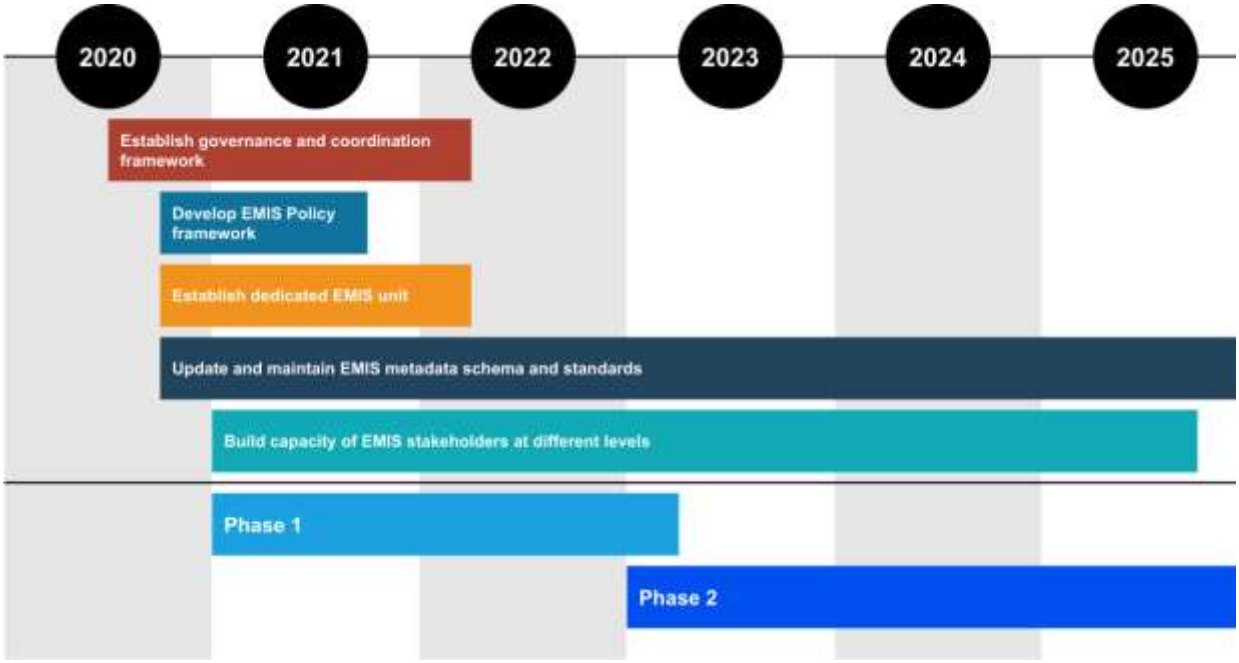


Figure 21: Implementation timeline for roadmap activities

5.1 Task 1: Develop EMIS Policy Framework

There are some policies and guidelines that guide current efforts, but they are inadequate to support a robust and fully functional EMIS in Rwanda. In order to address the challenges of the current EMIS regime, a holistic approach is required to deal with all the critical policy issues. Future EMIS development can then be anchored in a robust policy framework that clearly responds to the sector EMIS objectives.

Some of the currently existing challenges that can be addressed through a policy include:

i. Existence and emergence of parallel data systems within the education sector
ii. Duplication of effort in terms of data collection
iii. Existence of multiple quality standards
iv. Lack of a Data Sampling frame
v. Low response rates
vi. Poor identification of information needs among data producers (e.g., schools, local governments at various levels, sector MDAs) and users
vii. Lack of approved EMIS cycle calendar of events
viii. Poor dissemination of EMIS information and data
ix. Lack of sufficient skills among data producers and users

The new EMIS policy framework should clarify key issues that include:

i. Sector vision for EMIS;
ii. Roles and responsibilities of different EMIS stakeholders with mandate for data collection, quality verification, storage, analysis and dissemination;
iii. A clear legal mandate to collect information from all education and training institutions

and bodies, both public and private, for educational statistical purposes;
iv. Responsibility and ownership of data as well as procedures on how to share and access the data by third parties;
v. Respondents (issues of compliance and sanctions);
vi. EMIS Calendar of data collection (data production cycle);
vii. Allocating budgets and funding for EMIS and related activities to ensure sustainability.
viii. Data quality standards and quality assurance (conform to norms in the quality declaration of the national statistical systems and in other international statistical frameworks);
ix. Data privacy and confidentiality guarantee the privacy of data providers' individuality, the confidentiality of information they provide and its use solely for statistical purposes;
x. Data records maintenance (retention, archival and disposal).
xi. Data collection methodologies (data frame, registration of schools and institutions, registration of students);
xii. Information reporting requirements and accountability (timely and accurate for national, regional, continental and international education frameworks); and
xiii. Objectivity and impartiality, produce and disseminate education statistics respecting scientific independence, in an objective, professional and transparent manner in which all users are treated equitably.

Developing an EMIS policy framework with stakeholder buy-in and ownership will entail a number of activities that will include:

i. Needs Assessment—conduct consultations with key stakeholders at different levels (schools, districts, national)
ii. Synthesis and identification of key EMIS policy themes
iii. Formulation of draft EMIS policy and further consultations.
iv. Validation of the draft EMIS policy by the relevant stakeholders
v. Approval of draft EMIS policy by the MINEDUC and other pertinent stakeholders
vi. Dissemination of approved policy.

5.2 Task 2: Establish Governance and Coordination Framework

The development of an EMIS policy and its subsequent implementation will require a leadership and governance framework to oversee the various aspects of data collection and management across the entire sector. MINEDUC working with other stakeholders will need to establish an EMIS steering committee to:

- Steer the EMIS policy development process;
- Plan for change management and ensure smooth implementation by focusing on the wider impact of change particularly on people and how they, as individuals and as teams, move from the current status quo to the new desired state;

- Oversee the implementation of the EMIS policy; and
- Ensure that different stakeholders adhere to the technical (enterprise architecture) and organisational collaboration requirements necessary to support organised data collection and sharing.

The Steering Committee can establish technical committees that deliberate on specific issues like privacy, security, technical and semantic standards.

5.3 Task 3: Establish a Dedicated EMIS Unit with Multi-Level Support Structures

The aim of this task is to establish a centralised unit that drives education data collection, compilation and use across the sector through the provision of a reliable and secure EMIS infrastructure across the country.

The Unit will be responsible for the development of new applications in support of integrated education management information system and improvement on existing systems. It will oversee the refinement of integrated enterprise architecture. The Unit among others will be responsible for the management of educational statistics and data that will be used for projection, reporting and ESSP monitoring.

The unit will also coordinate training to ensure that users at different levels have the necessary skills to make maximum use of EMIS data and support initiatives that make more data available to key education stakeholders (e.g., students, teachers, parents).

The unit will work with support and technical assistance from RISA in the area of software development (e.g., Enterprise Application Integration) and Enterprise Architecture will be needed to ensure that the Unit access to the latest software development techniques, applications integration and interoperability standards.

5.4 Task 4: Create EMIS Metadata Schema and Standards

Metadata is a description of data (data about data). The primary role of metadata is to facilitate appropriate interpretation of educational data by both users and producers of data as well as information sharing and re-use. Metadata accomplishes this by providing adequate information about what the data mean and about the methodology used to collect and process them.

Metadata is the foundation on which information management systems are built and should be regularly updated. It is required to support the various uses of data, to manage the information and record life cycle, to verify data integrity, authenticity, and reliability, and to evaluate the relative importance of data and information for each contemplated use. This embedded information will shade more light on the content, context and structure of records when different activities occurred (e.g., data source, location, date, and time), entities involved (e.g., teacher ID, student ID and subject ID) and who captured the data (user ID). This also includes establishing unique identifiers to facilitate indexing and description of resources (e.g., data, documents) so that they can be located and consulted, facilitating data retrieval, maintenance, and audit.

Metadata allows MINEDUC to improve the sharing of education data across the sector, ensure interoperability across systems and standardise descriptions across education data collected by different stakeholders.

The development of metadata will require the establishment of a Working Group on education meta data and short-term technical assistance that provide training and support to users on adoption and creation of education metadata. Developing a metadata schema will entail a number of activities that may include:

- Defining and standardizing XML Schema for the education sector
- Study ISO 23081-1 and ISO/TS 23081-2 and international Dublin Core model (ISO 15836)
- Study other existing schemas and contact their creators
- Design the structure of the schema.

5.5 Task 5: Build an Integrated EMIS

The consulting team recommends that MINEDUC approaches implementation through a phased approach discussed in section **Error! Reference source not found.**. In phase 1, MINEDUC will i mprove SDMS and TMIS, eliminate a number of redundant systems like the National Examination Publications System (NEPS) and build a Data Services Bus and Education Data Warehouse (EDW). This will help foster dialogue amongst different sector stakeholders, provide an opportunity for collaboration to agree education metadata, work together to clean data and eliminate data quality issues in source systems (to minimise data errors and omissions), as well as help to build the necessary skills for successful data integration. Also, stakeholders will practice reusing existing data and agree requirements that bar them from developing new systems, unless such systems collect new data (e.g., not already being collected by an existing system and not in the EDW), target new data sources (e.g., users that do not interact with any existing system) and their functionality cannot be easily added to existing systems.

Phase 2 provides the ultimate integration of educational administrative data to learning resources information to monitor learning outcome in real-time, with seamless data sharing and service reuse between educational entities and a full linkage to other public sector data through the Government Service Bus.

5.6 Task 6: Capacity Building of EMIS Stakeholders at Different Levels

This project will be coordinated by the EMIS unit to nurture a data-driven culture across the education sector by equipping different stakeholders with training and skills to improve their ability to use education data and systems. The project will also promote the active use of education information to inform policy dialogue/choices, planning and decision making. Training should particularly be provided for those involved in data collection, analysis and use. Technical personnel will also be equipped with enterprise application integration techniques.

The project will produce a variety of resources to support both in-person and online learning

opportunities that include:

- Training manuals and resource guides
- Online self-learning modules/video on how to use different systems
- Training in data analysis and data interpretation
- Training to produce a variety of dissemination documents including school/district profiles, policy briefs, etc.

5.7 Risks and Mitigation

Table 12 provides some anticipated risks and planned mitigation strategies.

Table 12: Potential risks and mitigation strategies

Potential Risks	Mitigation Strategies
Some stakeholders may not be responsive or respond in a timely manner	As part of the change management plan, there is a need to provide stakeholders with comprehensive information about project benefits to ensure their full cooperation. Stakeholders should be invited to participate in crafting the EMIS policy and the resulting organisational structure and activities. The Project should also share an advance timeline of events with various stakeholders to ensure their availability and participation.
Systems are not fully documented, available, or accessible during necessary steps of integration.	Involve current system administrators in the integration exercise as participants as well as a learning exercise.
Poor data quality or unreliable feeds from any of the information systems	System integrators can implement rules to verify the data quality of different feeds, merge duplicate records or fields, in the data transformation software. Filtering rules can be used to ensure that only records that satisfy specific criteria are processed. Any failures need to be logged and reported back to primary system owners for rectification.
Data duplication across systems	
New data security issues may arise when data leaves source systems and is integrated in a Data Warehouse.	New data privacy and confidentiality requirements will be defined as part of EMIS policy. New protections must align with security requirements of the RGEA
Insufficient expertise is available for all aspects of data integration.	RISA has built up capacity in ICT and data design. It is willing to lend some of this expertise to government MDAs when the need arises or even to outsource for particular expertise if it is unavailable in-house.
Insufficient funding is available for all aspects of data integration including consultative processes and work activities.	Successful process will require to derive consensus among sector stakeholders. Priorities will be agreed upon and activities budgeted for so that stakeholders can mobilise resources.

5.8 Cost Estimates

Table 13 presents a cost estimate for each of the different projects that Rwanda needs to implement to attain an integrated EMIS.

Table 13: Cost implications of the road map

Tasks	Components	Cost elements	Estimated Cost (USD)
Develop EMIS policy framework to support the implementation of EMIS in Rwanda	• Consultation • Technical assistance • Publication and dissemination of policy • Policy implementation support	• External Consultant (USD60,000), • Three workshops for districts, education data experts and MDAs and 1 policy meeting (USD50,000) • Dissemination (US10,000)	120,000
Establish a Governance and Coordination Framework for an Integrated EMIS	• Setting up a steering committee • Setting up technical committees • Define interoperability requirements and standards • Organisation of regular consultation	• Meeting of technical committees over five years (12@2500) • Meeting of decision-makers (12@3000) • Awareness workshops on interoperability in education (USD50,000)	116,000
Establish a dedicated EMIS unit at MINEDUC with support structure at other levels	• Setting up a Unit • Enlisting technical assistance of three experts (enterprise architecture, systems development and enterprise application integration)	• Four long term external consultants obtained through RISA or internal secondments on EMIS to be based in Rwanda/MINEDUC at least for six months each @60,000 per year	240,000
Create EMIS metadata schema and standards	• Setting up Metadata Working Group • Short term technical assistance • Capacity building	• Metadata working group meetings 12@2500 • Two external experts on metadata for six months over two years period @45,000 per period)	120,000
Build an Integrated EMIS	• Technical personnel	• Technical advise/support (USD700,000). Focus	Phase 1: USD900,000

Tasks	Components	Cost elements	Estimated Cost (USD)
	• Development platform • Capacity building	for phase 1 is on database management, while for phase 2 on implementing SOA reference architecture. Some of this will encompass technical resources that RISA needs to access from the private sector. • Upgrades to SDMS and TMIS, Data Services Bus and EDW platforms in phase 1 (USD325,000). • Implementing different RGEA components in phase 2 (USD500,000). • Staff training and capacity building for EMIS Unit staff (USD300,000) for both phases. • Storage and compute costs at national data centre (USD175,000)	Phase 2: USD1,100,000
Build the skills of EMIS stakeholders at different levels: national, district and school	• Training on data collection, use and management • Training on enterprise application development • Training on enterprise architecture	• Data collection and use training for districts and schools (USD100,000) • Enterprise Application development training for EMIS Unit and others (USD120,000) • Enterprise Architecture training and examinations (USD70,000)	290,000

6. Summary

Rwanda aspires to transform from a low-income, agriculture-based economy to a knowledge-based, service-oriented economy with middle-income country status by 2035. Developing competitive human capital through promoting access, quality and equity of education by leveraging technology and data is a key priority. While the country has made a lot of progress in the education sector, the sector still faces a number of challenges including access issues, poor progression between lower classes, class repetition, as well as high dropout rates.

To address these and more, the Government of Rwanda (GoR) seeks to transition from merely tracking education coverage and access to better understanding of education quality and equity across different dimensions (MINEDUC, 2017). Efforts have been underway to develop databases and systems across the education sector by the Ministry of Education (MINEDUC), the Rwanda Education Board (REB), the Workforce Development Authority (WDA) and others like the Higher Education Council (HEC) and the Rwanda Polytechnic (RP). Unfortunately, these efforts have been driven by individual institutional needs and do not currently communicate with each other. This has made it difficult to share and reconcile data across institutions to better understand the overall performance of the whole sector.

GoR would like to integrate multiple kinds of data, from multiple sources within and external to the education sector to build an integrated Education Management Information System (EMIS) that supports business processes from a sector-wide perspective. The EMIS will provide a "single source of truth" and become a cornerstone for the management of the education sector by helping to monitor progress towards implementing the Education Sector Strategic Plan (ESSP). The integrated EMIS will also help drive the digital transformation of the sector by facilitating the use of technology and data in four key areas, namely – teaching and learning processes, professional development and empowerment of teachers, student support services and school administration (summarised in Table 7).

The gap analysis between the current and target EMIS states covered in section 3 highlights two broad challenges related to building an (EMIS) that include:

i. The institutional and policy challenge to be addressed through foundational activities like creating an EMIS policy (section 5.1), establishing an EMIS governance and institutional framework (section 5.2) and adhering to a common metadata framework (section 5.4).
ii. The systems integration challenge to be addressed through adopting enterprise architecture principles in a phased approach that builds on the best existing systems while phasing out duplication with minimal impact on current operations and activities.

The recommended 2-phase process to transition from the current state towards a fully integrated EMIS that conforms to the Rwanda Government Enterprise Architecture (RGEA) framework is detailed in Section 4. Phase 1 (Figure 14) involves the upgrading of SDMS and TMIS as building blocks for an EMIS with a Data Services Bus that provides Extract, Transform and Load (ETL) features to integrate data from various systems summarised in Table 9. SDMS and TMIS were selected as a foundation because the two systems contain key registries of critical data including schools, students, teachers

and the curriculum. Phase 2 (Figure 20) involves the deployment and leverage of more RGEA components that build on Phase 1 and further transition towards an integrated EMIS. Key components include a Government Service Bus (Section **Error! Reference source not found.**), D igital Identity and Security (Section **Error! Reference source not found.**), an Analytics Engine (Section **Error! Reference source not found.**), Communications and Collaboration (Section **Error! Reference source not found.**), an API Gateway (Section **Error! Reference source not found.**) and a Payments Gateway. All of these components will be available via a local and private Education Cloud (Section **Error! Reference source not found.**) Hosted at the National Data Centre.

Section **Error! Reference source not found.** provides a breakdown of the main cost elements for P hase 1 (USD900,000) while Section **Error! Reference source not found.** provides a breakdown of the main cost elements for Phase 2 (USD1,100,000). Please note that the above costs do not include the cost of other foundational roadmap activities that need to be implemented to facilitate successful adoption and use of an integrated EMIS. These additional roadmap activities are discussed in Section 5 and include:

i. Developing and implementing an EMIS policy to support the implementation of EMIS in Rwanda (Sections **Error! Reference source not found.** and **Error! Reference source not fo und.**).
ii. Establishing a Governance and Coordination Framework for an integrated EMIS (Section **Error! Reference source not found.**).
iii. Establishing a dedicated EMIS Unit at MINEDUC with support structures at other levels (Section **Error! Reference source not found.**).
iv. Development and adaptation of metadata and standards (Section **Error! Reference source n ot found.**).
v. Defining interoperability requirements that new school systems need to comply with to meet minimum standards (Section **Error! Reference source not found.**).
vi. Building the skills of EMIS stakeholders at different levels: national, districts, sectors and schools, to be able to collect, manage, disseminate and use data (Section **Error! Reference s ource not found.**).

Figure 21 shows an implementation timeline, while section 5.8 provides cost estimates for the different roadmap projects.

Depending on whether or not government has the necessary in-house expertise, some of these projects may require the support of external consultants. Should that prove necessary, capacity building should be a major element of the terms of reference.

Appendix A: References

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Appendix B: Datasets to Meet Educational Business Processes

Core Business Process	Education Areas	Data Requirements
Development and execution of strategies, laws and standards to make education available to the broadest possible cross-section of the community;	Entire education system	• Social and economic data (Population by age, GDP, average income) • National standards data (core standards for language, mathematics, science and technical subjects like computer literacy) • International standards data (core standards for language, mathematics, science and technical subjects like computer literacy) • Aggregate data from all education management systems (in support of policy goals – i.e. (57 indicators) are needed to track progress towards the attainment of the ESSP) • Quantitative data on the implementation of earlier policies, standards and strategies • Geographic information system data related to school and family locations in order to gauge coverage and student distances travelled to school
Support to the pre-primary, primary and secondary schools, vocational education, tertiary education and adult and lifelong learning in their effort to provide learning, teaching, research and innovation	Pre-primary	• Demographic records of young children, usually under the age of five years including family characteristics • Record on health and nutrition • Record on family support (child care) • Record on programme and curriculum • Record on teachers including professional development • Learning resources • facilities record • Programme records, structural observation of child development and child learning outcomes
	Schools	• Students – personal and family characteristics, previous educational experience, current grade, attendance, academic performance, behaviour, achievements/faults, outcomes (e.g. promotion to next grade, repeating grade, drop-out, transfer, or graduation). • Teachers – personal characteristics, past education, qualification, pre-service and in-service teacher training received, years of service, employment status, subject specialization, class/subject taught, teaching load, special skills, attendance, performance, behaviour,

Core Business Process	Education Areas	Data Requirements
		achievements/faults. • Finance – school budget and income by source, expenditure by type, financial balance. • Physical facilities – quantity and conditions of school buildings, classrooms, furniture, equipment and other physical facilities; maintenance, repairs and new constructions; rate of utilisation. • Teaching/learning materials – quantity and conditions by type of material, new acquisitions, rate of utilisation. • Learning achievement and outcomes – results of tests, examinations and assessments (regarding academic, behavioural and other student attributes). • Extra-curricular and co-curricular activities – type of activities, schedules, staff involved, number of participants, results, impact. • School and community interactions – school management board meetings, parent-teacher association activities, school-and-community activities.
	Vocational Education	• Students – personal and family characteristics, previous educational experience, current grade, attendance, academic performance, behaviour, achievements/faults, outcomes (e.g. promotion to next grade, repeating grade, drop-out, transfer, or graduation). • Teachers – personal characteristics, past education, qualification, pre-service and in-service teacher training received, years of service, employment status, subject specialization, class/subject taught, teaching load, special skills, attendance, performance, behaviour, achievements/faults. • Finance – school budget and income by source, expenditure by type, financial balance. • Physical facilities – quantity and conditions of school buildings, classrooms, furniture, equipment and other physical facilities; maintenance, repairs and new constructions; rate of utilisation. • Teaching/learning materials – quantity and conditions by type of material, new acquisitions, rate of utilisation. • Learning achievement and outcomes – results of tests, examinations and assessments (regarding academic, behavioural and other student attributes). • Data on training and further education for work related disciplines (including

Core Business Process	Education Areas	Data Requirements
		apprenticeships, trainee-ships, workplace and on-the-job training); • Joint ventures records with industry, schools and tertiary institutions to make use of facilities (including the provision of scholarships and study grants)
	Tertiary Education	• Students – personal and family characteristics, previous educational experience, current grade, attendance, academic performance, behaviour, achievements/faults, outcomes (e.g. promotion to next grade, repeating grade, drop-out, transfer, or graduation). • Teachers – personal characteristics, past education, qualification, pre-service and in-service teacher training received, years of service, employment status, subject specialization, class/subject taught, teaching load, special skills, attendance, performance, behaviour, achievements/faults. • Finance – school budget and income by source, expenditure by type, financial balance. • Physical facilities – quantity and conditions of school buildings, classrooms, furniture, equipment and other physical facilities; maintenance, repairs and new constructions; rate of utilisation. • Teaching/learning materials – quantity and conditions by type of material, new acquisitions, rate of utilisation. • Learning achievement and outcomes – results of tests, examinations and assessments (regarding academic, behavioural and other student attributes). • College entry requirements and students' success data • Standards and guidelines to support lecturers (including the provision of scholarships and study grants).
	Adult Learning	• Adult learners' demographics- personal and family characteristics, previous educational experience, current grade, attendance, academic performance, behaviour, achievements/faults, outcomes • Participation rate in basic literacy • Participation rate in functional/vocational literacy • Data on providers formal training • providers of community education offered outside formal institutional structures • Other providers including distance learning

Core Business Process	Education Areas	Data Requirements
School nutrition and feeding	Basic education	• Number of school children receiving meal at school desegregated by gender, grade and type of school feeding (Mandatory) • Number and percentage of total "monthly" school days with school feeding per grade (Mandatory) • Number of days food from at least four food groups is provided ◦ Grains/cereals, roots and tubers; ◦ Diary products; ◦ Legumes, nuts and oilseeds; ◦ Animal products (flesh foods); ◦ Eggs; ◦ Vitamin A-rich vegetables and fruits; ◦ Other vegetables and fruits. • Type of food crop source (school garden, local farmer, local trader, local market or cooperative, parent contribution, other source) • Parental contribution amount (RWF) per term per child and grade • Percentage of student's whose parents, guardian or sponsor contribute to school feeding through cash per term • Percentage of student's whose parents, guardian or sponsor contribute to school feeding through in kind contributions per term
Curriculum Development	All education levels	• Data on current syllabus and curriculum • Qualitative and quantitative analysis of the problem of curriculum framework • Student achievement data both national and international • Teaching and learning resources • Data on issues and problems with the current curriculum (relevance, currency, flexibility, meeting government labour policy, inconsistency between curriculum and examination) • International comparison on curriculum currency • Student and teachers' feedback data • Curriculum development process (financial, human and material resources, timeline, structures, processes, strategies)

Core Business Process	Education Areas	Data Requirements
Further development and management of learning resources	Educational Indicators	• Average class size • Average distance travelled by students to get to educational facilities • Educational expenditure by different level of educational institutions • Average school expenditure for different aspects (e.g. Maintenance, feeding • Education personnel by age • Ratio of academic staff to management and support personnel • Educational personnel by institution • Enrolment by age • Enrolment by field • Enrolment by level of educational institutions • Enrolment of non-citizen students • Graduates by age, field, level of education and type of institutions
Research and innovation	Entire Education	• Information on research in niche area • Title and project registration • Domain of research • Research progress • Research repository • National collaboration • Industry collaboration • International collaboration • Publication and reports
Content and Learning resource management	All education levels	• Learning resources • Collaborative tools • Learning Path • Tracking/Reports • Shared Question Pool • Web conference • Assessing Performance • Deployment of Content

Core Business Process	Education Areas	Data Requirements
		• Providing Administrative Functions • Tracking of learners
Public relation and international cooperation	Tertiary	• Promotion policy and strategy • Promotional products and channels • Data on internal relation between students, administration and teachers • Data on inquiries
Learning outcomes assessment	All education levels	• Reports • Grades • Progression • Assessments • Awards
Infrastructure and asset management	All education levels	• Facilities • Planning • Inspections • Maintenance and repairs • Transactions • Reports • Inquires • Asset tracking
Document management	All education levels	• Capturing • Versioning • Metadata • Search and retrieval • Archiving
Human resources management	All education levels	• Payroll • Recruitment and hiring • Human resources planning • Performance Evaluation • Employee Movements

Core Business Process	Education Areas	Data Requirements
		• Welfare Administration • Health and Safety Administration • Discipline Administration • Compensation Management • Training and Development
Financial management	All education levels	• Budget • Account payable • Account receivable • General ledger • Purchasing • Inventory control