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Education Systems Interoperability: Implications for Privacy and Security in Educational Management Information Systems

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Abstract
The importance of robust Educational Management Information System (EMIS) becomes very essential in addressing the complexities of data management, particularly as Nigerian educational systems is progressively leveraging the interrelated platforms in order to enhance operational efficiency and data sharing. However, educational sector is faced with several related challenges like: fragmented data, management systems, data privacy concerns, inadequate technology infrastructure, interoperability that is poor between different platforms, and lack of standardized protocols. These challenges made most institutions of learning to compromise the security and integrity of sensitive information. This study presents conceptual model that exemplifies the synergistic interactions among the major components of EMIS, by stressing the main roles of interoperability, security and privacy. Interoperability is central and surrounded by Data Governance, Technology Infrastructure, Privacy Measures, Regulatory Compliance, Security Measures, and Stakeholder Engagement. Each of the components is interconnected to illustrate how technology infrastructure enable effective data exchange while preserving sensitive information. The integration of these components in the proposed model offers qualitative understanding for educational institutions to strive well in enhancing EMIS while securing stakeholder's privacy. This strategy addresses the present limitations of EMIS in Nigeria, opening way for a more efficient and safe educational data management system. It is recommended that educational institutions should be encouraged in adopting standardized procedures for seamless integration of EMIS in order to facilitate overall functionality and efficient exchange of data. Also, institutions should develop clear data governance policies that prioritize privacy and security, ensuring regulatory compliance and promoting responsible data use through regular training and awareness programs.

Keywords: **Interoperability, Privacy, Security,** Educational Management Information Systems (EMIS).

1. Introduction

The rapid advancement of technology in the 21st century has significantly transformed educational domain via implementation of Educational Management Information Systems (EMIS). Education Management Information System (EMIS) is now the focus of research in academic environment due to its inherent potential for shared, reliable, timely, integrated and efficient utilization of data for decision making and proper planning in tertiary educational system [1]. The author further attested that it can be argued that a technical approach to EMIS integration based on the scalability, performance and interoperability being the three key purposes for EMIS integration in any system of education.

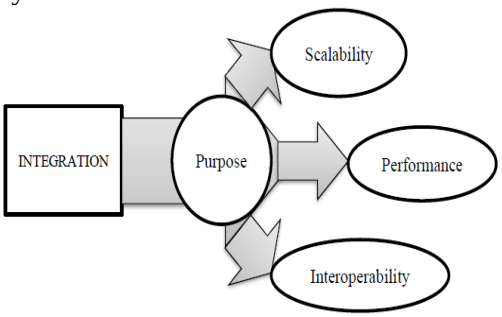

Figure 1: The 3 Key Purposes of EMIS Integration
Source: Adenubi [2]

The 3 key purposes (Scalability, Performance and Interoperability) of EMIS Integration is represented in Figure 1 for description as thus:

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Scalability: has to do with the need for the integration of several EMIS with the purpose of increasing its functionalities and scope of operations. In this respect, scalability can be attained by upgrading EMIS with new module extensions (horizontal scalability) or by linking new functional EMIS to existing structure of EMIS (vertical scalability).

Performance: involves the need for the integration of EMIS with the purpose of enhancing its functionalities. In this respect, the performance of EMIS can be enhanced by extending access and processing of information from different sources in order to offer a more comprehensive understanding of information. Thus, performance can be realized with scalable EMIS, however, scalable EMIS might not be able fulfill the intended performance objectives.

Interoperability: entails establishing technical standards that is aimed at facilitating exchange of communication and data across platforms with varying information and communication semantics.

The concepts of **integration** and **interoperability** are both essential for optimizing data management, improving decision-making processes, and enhancing the overall efficiency of educational institutions. These terms are more often used interchangeably to denote different approaches to managing data and systems within EMIS. The primary distinction between integration and interoperability lies in the depth of connection and the specific objectives each aims to achieve. Integration entails combining systems into a cohesive whole, establishing a streamlined environment where data flows effortlessly between all components. This method is typically often more extensive demanding considerable effort in data transformation, system architecture and technical execution [2].

Conversely, interoperability focuses on allowing different systems to communicate and exchange data without the need to merge them into a single platform. It aims to establish a network of systems that can interact seamlessly using shared protocols, enabling each system to retain its autonomy while contributing to a broader and more efficient data ecosystem [3].

Both integration and interoperability are essential for educational institutions to manage their data efficiently. However, the decision between the two depends on the institution's unique needs, available resources, long-term objectives [4]; and data governance.

Both integration and interoperability contribute to enhancing the functionality and efficiency of EMIS, though they do so in distinct ways. Integration seeks to build a unified system that consolidates all educational data in a single location, while interoperability enables communication between independently functioning systems, ensuring seamless data flow across platforms. Interoperability is a critical feature of EMIS that is been described as the ability of different systems to seamlessly utilize and exchange data. Adenubi [2] affirmed that the primary goal of integrating various enterprise application systems in the context of achieving interoperability is to ensure that each system can access and utilize shared data.

2.0 Relate Woks

Considering the synergistic relationship among the components of EMIS and their relevance for effective integration into Nigerian educational system, Mohd Hasan and Abdulmonem [4] found out that education institutions are leveraging EMIS to create a more dynamic electronic environment for faculty, students, and alumni by a selecting single entry point for registration, communication, class and content management, research and collaboration. The findings was premised based on the postulation that EMIS empower faculty members and students, reduce the cost administration, enhance visibility of information and enable institution of education to achieve agility in business. Figure 2 showed the design approach of EMIS as suite of enterprise applications by Adenubi [2].

The choice of this operation is more flexible, effective and scalable, base in the fact that it facilitate increasing need for upgrade in the system of education to be accomplish by different application developers. This assertion confirmed that EMIS is developed for diverse context and purposes using different standards and languages.

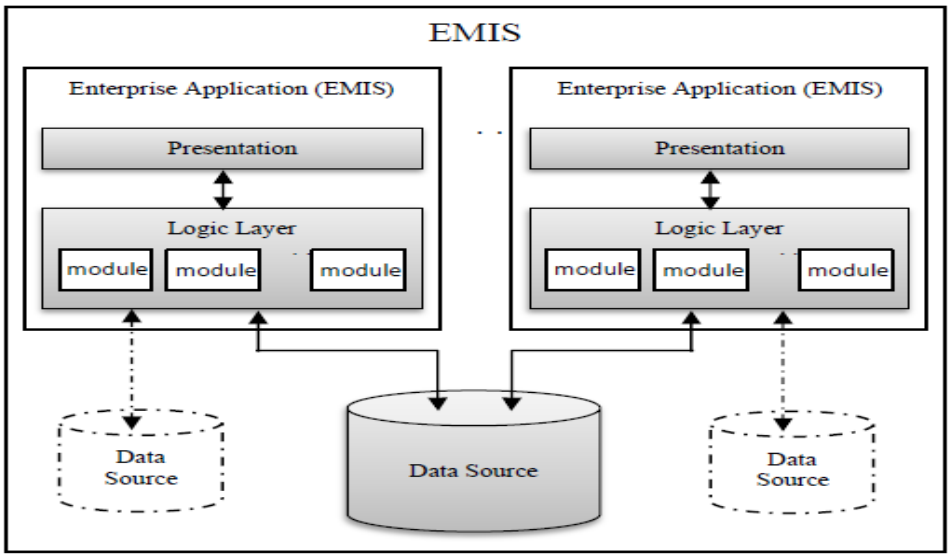

Figure 2: Design Approach of EMIS as Suite of Enterprise Applications
Source: Adenubi (2021a) [1]

The variances in the purpose, context, standards and language have implication on integration of these different EMIS to interoperate for smooth data exchange. Aserey and Alshawi [3] affirmed that EMIS was developed for different related purposes like student record management, financial management, assessment management, among others. The differences in the purpose and context of the EMIS, which informed their respective underlying logic and structure, limit the integration of the different EMIS to achieve seamless data exchange for cross-purpose data analytic across different education institutions. The integration challenges have constrained EMIS from reaching its full potential in enhancing education.

The challenge evolves in redefining and standardizing the development of EMIS to function as a fully integrated system capable of seamless interoperability. Interoperability allows integrated EMIS to exchange and share data, which form the basis for using EMIS to achieve efficient administration in education system Adenubi [2]; thereby enhancing **privacy and security of data in EMIS.**

The interoperability of EMIS is to enhance collection, management and analysis of educational data, and supporting decision-making processes at various levels of educational administration [5]. The paradigm shift in technology has driven most educational institutions to depend on interconnected platforms for data sharing and operational efficiency in order address to complexities of data management, security and privacy related issues that is surrounding usage and interoperability [6].

Interoperability allows numerous institutions of education to access vital information and share it across various platforms, thereby enhancing collaboration and enabling data-driven decision-making. The growing demand for interoperability has driven educational institutions to rapidly adopt measures that are aimed at enhancing operational efficiency and learning outcomes by highlighting the needs for robust frameworks that oversee data sharing while ensuring the good protection of delicate and sensitive information.

The growing demand for interoperability has driven educational institutions to rapidly adopt measures aimed at enhancing operational efficiency and improving learning outcomes, highlighting the need for robust frameworks to manage data sharing while safeguarding sensitive and delicate information. Zhang, Wu, and Zhang [7] described data governance to comprise standards procedures and policies that exemplified how data is collected, accessed, used and stored. Jansen and van der Voort [8] further reiterated that effective data governance ensures data integrity, accuracy and accountability, which are paramount factors for substantiating the trust of stakeholders (tutors,

students and parents), rely immeasurably on accurate data for decision-making.

Subsequently, strong data governance framework has a contributory factor in aligning with regulatory compliance, which according to Kuchta, Piekarz and Kaczmarek [9], emphasized on strict adherence to the laws that protect personal information, such as the General Data Protection Regulation (GDPR), Nigerian Data Protection Regulation (NDPR), and Family Educational Rights and Privacy Act (FERPA). The synergistic relationship between security and privacy measures further highlights the complexities involved in managing educational data. Privacy measures focus on protecting personally identifiable information (PII) and safeguarding that data handling practices align with the established privacy regulations [10]. Contrary to this, security measures are concerned with the safeguarding of data against unauthorized breaches, access and other related cyber threats [11]. (Anderson, 2018). Both security and privacy measures are crucial for creating safe and dependable environment for data sharing, and must be integrated into EMIS framework to maintain and protect stakeholders' rights and data integrity.

Stakeholder engagement plays a critical role in EMIS environment by encouraging communication and collaboration among personalities that are involved in the educational process. The active engagement of stakeholders in discussions that relates to data usage, privacy, and security enhances transparency and builds valid trust among them. The feedback generated from the stakeholder provides appreciable insights into effectiveness of data governance practices, interoperability initiatives, and security measures, which facilitate the creation of continuous improvement cycle that has advantageous variables on educational system. However, Nigerian education sector faces several challenges that hinder effective implementation of EMIS, including lack of interoperability across platforms, fragmented data sources, limited technological infrastructure, and data security and privacy concerns [1]. McKinsey and Company [12] affirmed that inconsistent data governance practices, resistance to change, inadequate stakeholder engagement, and the absence of standardized protocols further complicate EMIS integration (Aserey & Alshawi, [3]; Mohd Hasan & Abdulmonem [4]). The proposed integrated EMIS model addresses these challenges by promoting interoperability, enhancing data governance, upgrading technological infrastructure, ensuring privacy and security, and fostering stakeholder collaboration.

3.0 Components in the EMIS Interoperability Model

The existing literature emphasized on the importance of these components, however, research gaps exists as many studies discuss interoperability, privacy, and security in isolation. Few of these studies integrated these concepts into a cohesive framework that shows their interdependencies within the context of EMIS. Subsequently, there are inadequate empirical research that explores how educational institutions in various developing countries like Nigeria implement these frameworks in practice. The recent studies investigate the roles played by the stakeholder engagement in assessing the effectiveness of data governance and security measures in emphasizing the need for research that integrates this dimension.

Therefore, this study suggests a synergistic model that integrates these components (technology infrastructure, security measures, interoperability, privacy measures, data governance, regulatory compliance, and stakeholder engagement) into a unified framework for EMIS. Having better comprehension and leveraging the interconnectedness of these elements will enable educational institutions to enhance stakeholder trust, EMIS platform and promote data-driven culture that may lead to improved educational outcomes. Figure 1 shows a sketch of the synergistic model for **Interoperability, Privacy, and Security in EMIS.**

3.1.1 Synergistic Relationship of Components in the EMIS Interoperability Model

EMIS emphasizes the interconnection of multiple key components. The synergistic model for EMIS emphasizes on the interconnection of numerous major components: Data Governance, Technology Infrastructure, Privacy Measures, Regulatory Compliance, Security Measures and Stakeholder Engagement.

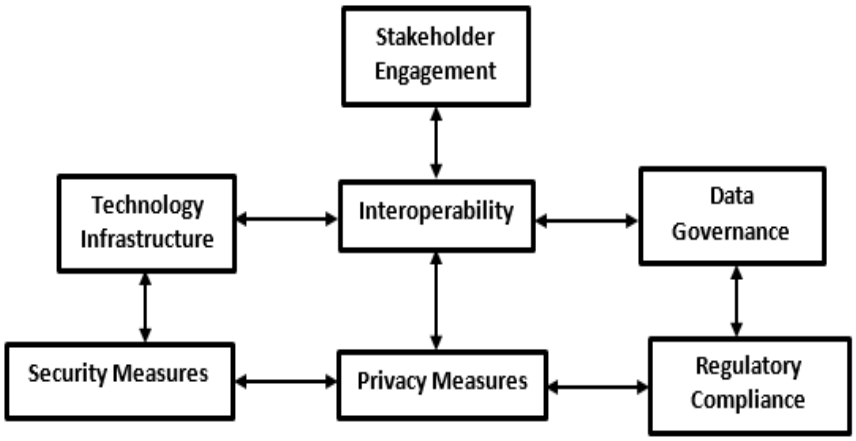

Figure 1: **Synergistic Relationship of Components in the EMIS Interoperability Model**

Knowledge of these relationships is fundamental to leveraging the benefits of interoperability while protecting sensitive data and information. The synergistic relationships among these components are briefly discussed hereunder:

a) **Interoperability (Central to the Model):** is positioned at the center, link all other components and emphasize its paramount significance for relatedness to all the components. Interoperability serves as the core component to enhance seamless data sharing among various educational systems. It also enables institutions to disseminate vital information effectively, which is very important for data-driven decision-making. The effectiveness and efficiency gained via interoperability relies heavily on the productivity of the surrounding components.

b) **Technology Infrastructure:** showing that effective technology is indispensable for both data protection and exchange; it is connected to interoperability and security measures.

Synergy with Interoperability:

i. **Facilitator of Data Exchange:** a well-designed technology infrastructure offers hardware and software that are necessary for systems to communicate and disseminate data. Studies reiterates that infrastructure must support various standards (like protocols and APIs) to enhance interoperability between different educational systems.

ii. **Impact on Security Measures:** technology infrastructure also plays a critical role in implementing security measures. Provision of security measures on modern network architectures can support encryption technologies that protect information and data during dissemination by enhancing security while facilitating interoperability.

c) **Data Governance:** demonstrates its role in managing data standards and policies by its linkage to interoperability, privacy measures, and regulatory compliance.

Synergy with interoperability and other components:

i. **Framework for Data Management:** data governance encompasses standards, policies, and procedures that can enhance management of data integrity, accessibility, and usage. One of the major factor associated with strong data governance frameworks is to enable that the shared data across interoperable systems is accurate and highly reliable.

ii. **Influence on Privacy and Compliance:** effective data governance has direct impact on privacy measures by defining how sensitive data are handled, stored, and disseminated. It is to ensures that organizations remain compliant with General Data Protection Regulation (GDPR), Family Educational Rights and Privacy Act (FERPA) and Nigerian

Data Protection Regulation (NDPR); thus promoting a responsible approach to data management.

d) **Privacy Measures:** emphasized the need for privacy protection in a connected environment by its connection to interoperability, data governance, and security measures in the model

Synergy with Data Governance and Security Measures:

i. **Protecting Sensitive Information:** privacy measures involve practices designed to protect personally identifiable information (PII) and ensure high level of confidentiality. According to Kumar, Singh and Saini [5], protecting personally identifiable information must be aligned with data governance frameworks in order to ensure compliance and proper data handling.

ii. **Reinforcement of Security Measures:** privacy and security measures work hand-in-hand. Security measures protect data from unauthorized access, while privacy measures dictate the protocols for data usage. For instance, encryption can be seen as a security measure, while consent for data use represents a privacy measure. Both privacy and security measures are essential for adequate protection of data.

e) **Security Measures:** exemplified the importance of securing the technological framework while protecting sensitive data. ***Security Measures*** was positioned to connect to both Technology Infrastructure and Privacy Measures.

Synergy with Technology Infrastructure and Privacy Measures:

i. **Defensive Layer:** security measures protect the integrity and availability of data within the technology infrastructure. Anderson [11] found out that implementing robust authentication mechanisms, intrusion detection systems and firewalls helps to safeguard against potential threats.

ii. **Supporting Privacy Goals:** security measures does not only protect against external threats, but also sustain the goals of privacy measures. Preventing unauthorized access to security protocols that is designed to ensure that only authorized personnel have access sensitive information to maintain privacy.

f) **Regulatory Compliance:** signifies that adherence to laws and regulations is very essential for effective operation of EMIS. Therefore, linking Data Governance, Privacy Measures, and Security Measures together in the model.

Synergy with Data Governance, Privacy Measures, and Security Measures:

i. **Framework for Legal Adherence:** regulatory compliance establishes a legal framework for how data should be managed and protected. Compliance with laws such as FERPA and GDPR requires institutions to implement strong data governance and privacy measures, thereby making regulatory compliance a key driver of organizational policies.

ii. **Impact on Stakeholder Engagement:** compliance with regulations promotes trust among stakeholders by encouraging them to engage fully with the educational systems. When stakeholders believe that their data is protected and handled appropriately, they are more likely to share information and participate actively in educational initiatives.

g) **Stakeholder Engagement:** **stakeholder engagement** highlight the need for collaboration among all stakeholders involved in the educational process. That is why it was positioned above the central node with connections to both Interoperability and Data Governance.

Synergy with Interoperability and Data Governance:

i. **Collaboration for Better Outcomes:** engagement of stakeholders (administrators, students, and parents) in governance processes and data use

and privacy measures enhance transparency and building trust which is vital for successful data sharing [12].

ii. **Feedback Loop:** active engagement of the stakeholder provides valuable feedback on effectiveness of data governance practices and interoperability. Stakeholders can highlight challenges they face in data handling, suggest improvements and create continuous improvement cycle.

The synergistic relationships that exists among the components in the EMIS interoperability model exemplify that efficient educational management hinges on holistic approach. Interoperability is central to other components on which all other components revolves around in order to enable efficient exchange of data while ensuring security and privacy are given high paramount importance. A cursory attention given to the interconnectedness among these components will go long way to improve stakeholder trust, enhancement of EMIS in educational institutions, and promoting data-driven culture that can enhance better educational outcomes. The synergistic effect and strength of each component reinforces others by creating favourable environment that can maximally harness the benefits of technology in education while addressing the major challenges of privacy and security.

4 Contextualizing the Synergistic Relationship of the Components in EMIS to Nigeria Educational System

The system of educational in Nigeria presents exceptional scenario for assessing the synergistic relationship among the components of EMIS. Implementing effective EMIS becomes critical as Nigeria grapples with related challenges like limited resource, infrastructural deficits, and the need for data-driven educational reforms. Therefore, having good understanding on interdependencies that exists among interoperability, technology infrastructure, data governance, privacy measures, regulatory compliance, security measures and stakeholder engagement can be a major factor for contextualizing the enhancement of effective Nigeria educational systems. The followings are considered as factors:

a. **Interoperability in Nigeria's Educational Systems:** most Nigeria educational institutions are faced with interoperability challenges among data systems that are hindering effective decision-making and resource allocation. Study conducted by Ndukwe [13] found out the many state and federal agencies operate on separate databases for examination results, student enrollment and teacher performance. This challenges made accessing detailed educational data difficult. However, promoting interoperability in educational institutions facilitates easy sharing of information across platforms and leads to better insights into institutional effectiveness and student performance. This tendencies enhance the development of a unified national database for tracking educational progress and implementing reforms [14].

b. **Technology Infrastructure:** majority of educational institutions in Nigeria suffer from inadequacies of technology infrastructure; including outdated hardware, limited access to reliable internet, and insufficient training for administrators and educators. Akinola, Adedeji and Olaniyan [15] asserts that a robust technology infrastructure is a foundation for supporting collaboration across educational systems and data sharing, therefore recommends huge investments and procurement of technology infrastructure that include provision of modern computing facilities, upgrading network capabilities and ensuring access to modern digital technological tools for all stakeholders. Therefore, investments in technology infrastructure are necessary for interoperability to be efficient and effective.

c. **Data Governance:** data governance in Nigeria's education sector is still in its developmental stage with numerous institutions of learning lacking reputable policies and procedures for data management [16]. According to Adetunji and Adebowale [17] and Udo

Uche and Oko [18], Nigerian educational institutions can derived numerous benefits from developing detailed data governance policies that expresses usage, data ownership and accountability while promoting tradition of data stewardship among educational stakeholders. Hence, a strong data governance framework is crucial for data quality, accountability and compliance with regulations [19].

d. **Privacy Measures:** privacy related issues are crucial in the Nigeria educational context due to prevalent data related breaches and unauthorized access to personal information [20]. The authors further attested that establishing strong privacy measures is indispensable to protecting students' and teachers' personally identifiable information (PII). This strategy can be accomplished via implementation of policies that oversee consent, data collection and access rights [21]. Therefore, creation of awareness campaigns to educate stakeholders on the attributable importance of privacy and judicious use of data that will foster a tradition of data protection [22]; cannot be over emphasized.

e. **Security Measures:** the need for vibrant and stronger security measures is very vital in Nigeria due to growing reliance on digital platforms for educational data management. Danjuma and Abubakar [23] and Nwankwo, Babalola and Ajiboye [24] attested that cybersecurity threats have been causing substantial risks to the confidentiality and integrity of educational data. Therefore, Strengthening security measures will not only protect sensitive information and data but also strengthens stakeholders' trust in the educational systems. Ibrahim and Fagbemi [25] recommends that various institutions of learning should invest heavily in cybersecurity through implementation of encryption protocols, staff training and establishing incident response plans to safeguard data breaches.

f. **Regulatory Compliance: the importance of** regulatory compliance in securing data integrity and protecting the rights of stakeholders in Nigeria's educational systems cannot be over emphasised. Akpan and Akomolafe [26] affirmed that Nigeria has not sufficiently improve on the technical expertise related to Data Protection Regulation (NDPR) awareness and strict adherence to regulations among educational institutions. Obi, Okwor and Nwankwo [16] affirmed that absolute compliance with data protection laws requires all institutions to launch sound procedures and policies for data handling via provision of intensive training of institutions staff, and engagement in routine audits to assess levels of regulatory compliance.

g. **Stakeholder Engagement: e**ngagement of stakeholders (students, teachers, parents and various government representatives) plays an important roles in enhancing conducive collaborative environment for effective data utilization and governance [27]. Studies showed that engagement of stakeholders in cutting-edge discussions about data security, privacy and usage will go a very long way in enhancing transparency, accountability and building trust on interoperability of educational systems. Creation of avenues for feedback and discussions via engagement with stakeholders will enhance identification of perennial challenges and proffer solutions to EMIS.

The contextualization of the synergistic relationship among the components of EMIS to Nigeria underscores the need for integrated approach to data management in the educational sector. The proposed model serves as a prototype for policymakers and practitioners that are working to strengthen the educational system of Nigeria. Therefore, solving perennial challenges that are associated with technology infrastructure, interoperability, privacy measures, data governance, security measures, stakeholder engagement and regulatory compliance will enable Nigerian educational institutions to improve upon EMIS operational

system, improve upon data-driven decision-making and enhance educational outcomes.

5. Conclusion

This study explores the synergistic relationships that exists among the components of EMIS and their impacts on security and privacy in Nigeria educational system. The components of EMIS that were examined include technology infrastructure, interoperability, data governance, security measures, privacy measures, regulatory compliance and stakeholder engagement. Each component of EMIS synergistically interact with others in order to create a single framework that enhances the inclusive functionality. A balanced comprehension of these relationships highlights the importance of a holistic approach to management of data in educational institutions.

This approach improves data integrity, accessibility and critical issues that surrounds data privacy and security in the context of Nigerian regulatory frameworks. The study further buttresses that successful implementation of EMIS in Nigeria educational sector pivots on recognizing and enhancing the existence of synergistic relationships among its components. Judicious application of this model in various educational institutions can tremendously improve data management practices by investing in technology infrastructure, optimization of interoperability and establishing vibrant privacy measures and data governance. Also, engagement of stakeholders in decision-making process can reinforce data privacy and security; thereby leading to compliance with fortified trust and data protection laws.

The study further buttressed that a well-functioning EMIS will contribute immeasurably to national growth and development via provision of accurate data for policy formulation and resource allocation. Therefore, this integrated approach will overcome the perennial challenges facing educational sector in achieving sustainable improvements in educational outcomes.

5.1 Recommendations

The following recommendations are proposed, specifically targeting key stakeholders in educational sector:

1. **Government Agencies under auspices of Ministry of Education and National Information Technology Development Agency should l**aunch a clear guidelines and policies that promotes interoperability, data governance and security within EMIS.
2. Intensive training programmes should be organized for educational administrators and Information and Technology staff to enhance better understanding on privacy measures, data management, and cybersecurity best practices (such as data encryption and regular audits).
3. **Government and non-governmental organizations should a**llocate resources for upgrading technology infrastructure (including software, hardware, and internet access) to support effective EMIS implementation to **all educational institutions.**
4. Government bodies and regulatory agencies should provide funding and technical support to help institutions update the outdated hardware and secure reliable internet connections.
5. Data protection officers and information technology specialists should be encouraged to collaborate with educators, administrators, and regulatory bodies to continuously improve EMIS tools and respond to emerging data challenges.
6. **Information Technology service providers** should be encouraged to provide continuous technical support and maintenance for EMIS systems to ensure their effective functioning and adaptability to emerging needs.
7. **Information Technology service providers** should be provided with adequate newer technologies to collaborate with educational institutions to design and implement user-friendly EMIS platforms that facilitate easy access to data while ensuring robust security features.

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