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Towards a Unified University Information System: Bridging the Gap of Data Interoperability

Orobor Anderson Ise*

Information and Communication Technology Unit, Federal University of Petroleum Resources Effurun, Delta State, Nigeria
*Corresponding author: orobor.ise@gmail.com, orobor.anderson@fupre.edu.ng

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Abstract As the need for universities to securely and timely share data with the National Universities Commission (NUC) becomes more imperative, NUC had introduced the Nigeria University System Management Portal (NUSMAP) that act primarily as a data collection portal from all the universities. The portal enables universities to upload students, academic and non-academic staff, and other related data to it. The process involves manual data collection through vast disparate information systems which makes it highly people dependent and susceptible to delay, inconsistency, redundancy and erroneous data entry / uploading. This research work however, suggests that adoption of interoperable framework will be a better approach to such unification. It therefore proposed a framework based on Service Oriented Architecture (SOA) that will enable disparate information systems used in universities to interact and seamlessly share data securely between themselves, NUC and other private/public agencies. It also hoped that it will act as a spring board for researchers from agencies, industries and academia to start advocating standardization of common education data as well as adoption of interoperable framework in educational sector. This will ensure conformance to standardize data exchange in Nigerian universities as educational practice and technology are rapidly changing from print to digital.

Keywords: *interoperability, SOA, standard, Unified Universities, NUC, web service*

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1. Introduction

Using data to shape decisions has long been a hallmark of high-performing organizations. The growth of available technology provides educators more timely and user-friendly access to data, especially longitudinal data, and with an increasingly mobile student population, sharing those data across states and higher education systems have never been more imperative [1].

Traditionally, the standalone applications used by school have the limitation of data isolation. It is difficult to access and share data. Data isolation could also result to redundant data entry, data integrity problems, and inefficient or incomplete reporting. In such cases, a student's information can appear in multiple places but may not be identical. For example decision makers may be working with incomplete or inaccurate information. Many schools also experience an increase in technical support problems from maintaining numerous proprietary systems.

Building systems that adhere to a set of standards can enable independent systems to interact with one another. This increases building management capabilities, improves operating efficiency and flexibility, and reduces installation and expansion costs. Interoperability can help to remove the barriers and change islands of information to a seamlessly integrated whole [2].

Stevenson and Ruddock [3] argue that systems will move more towards the seamless integration of resources because in the digital age the ability to search for resources efficiently and effectively is a basic expectation of users. Integration saves users time, pulls together archives, enables researchers to make new connections, and it pools the experience, expertise and resources of archivists for optimal use.

1.1. Background Study

The need for universities to access and share resources across the nation with the National Universities Commission (NUC), for the purpose of facilitating learning, teaching, research and service delivery has become imperative.

NUC in its effort towards digitizing the Nigeria university system, facilitating the development of many other knowledge areas of university system and ultimately aiding Nigeria universities to be among the world best has initiated several projects. For example, on Friday 7 September 2012 the commission inaugurated its first Online Programme Accreditation Portal. An initiative aimed to fully automate the accreditation process of Universities' Academic Programmes as carried out by the NUC in order to ensure that the Minimum Academic Standard Document in every programme is attained, maintained and fully complied with by universities as

required by the laws establishing the commission [4]. The idea was aimed at addressing the challenge of poor ranking of Nigerian universities by making them more internationally visible. The new accreditation portal will also include other academic deliverables such as automation of database of all universities in Nigeria with link to the NUC [5].

The initiative is seen as a major stride forward by the NUC in making access to information more transparent and easier in carrying out its oversight functions [4].

The introduction of NUSMAP is to enhance academic deliverables, such as the automation of database of all universities in Nigeria, to maintain accurate records of their activities, for proper monitoring and to ensure compliance with NUC's standards. It holds a lot of prospects for the Nigeria University System (NUS). It will serve as a reference for accreditation and other exercises as well as making the process more efficient. It would also reduce the stress of carrying hard copies of Self-Study Forms, used in accreditation while addressing the challenge of poor ranking of Nigeria universities, thereby making them more visible on the world map [6].

The objective of this paper is:

1. To propose interoperability framework that sets and defines standards for common education data exchanged. This will enable educational data sharing between universities, NUC and other agencies.
2. To provide knowledge and raise common awareness and understanding about interoperability framework as the optimal solution to seamless unification of Nigeria universities information systems.
3. To set the roadmap for the development of such framework that will act as a bridge between applications in Nigeria universities, NUC and other agencies.

1.2. Motivation: NUSMAP

University information systems today are incapacitated in data sharing amongst themselves due to the problem of interoperability. Currently, application available to NUC is NUSMAP. NUSMAP automates the databases of all universities by enables universities share and communicate data with NUC by uploading them through a proprietary web interface and in Excel document format to its database.

Technically NUSMAP does not solve the problem that exists with the heterogeneous university information systems as:

1. University applications and their data remain isolated from each another.
2. Applications still lacks interoperability as such cannot share data amongst themselves as well as with other public/private agencies that might need it.
3. Redundant data entry exist in multiples information systems.
4. Disconnected applications increase support costs.
5. Common education data exchanged are not standardized.
6. Data reporting are inaccurate, inconsistent, erroneous and delayed.

Though NUSMAP eventually gets the data where it is needed by NUC, the process requires at every point in time reading information from disparate information systems and then re-entry/uploading then to the portal. This is so because NUSMAP and these systems does not interoperate as such lack basic communication standard for data exchange. The process automatically inherits all the risk associated with data migration. NUSMAP is extremely people dependent and it is seen as an unsustainable approach to ever growing demands for secure and timely access to highly accurate educational data.

In addition, NUSMAP does not cater for easy access to educational data by other agencies that might need it. This research therefore, suggests that a holistic approach to such unification should begin with development of educational interoperability framework. The framework will define common educational data format and rules for their exchange. The adoption of this framework will facilitate common data exchange and seamless integration of disparate university information systems.

1.3. Related Works

Several organizations and initiatives have undertaken the task of facilitating and improving educational data interoperability. Some of them are:

1.3.1. School Interoperability Framework (SIF)

SIF is a data sharing open specification for academic institutions from Kindergarten through Grade 12 (K-12). The framework defines a set of rules and definitions for application to share data across k-12 schools [7]. Over the past few decades, most school systems have adopted SIF to solve data interoperability, accessibility, and reporting challenges in education through a standards–based information technology infrastructure and technologies [8].

1.3.2. The Ed-Fi Solution

The Ed-Fi solution is an educational data tool suite that enables vital academic information on K-12 students to be consolidated from the different data systems of school districts while leaving the management and governance of data within those districts and states [9].

1.3.3. Edfacts

EDFacts is a data initiative of the U.S. Department of Education (USED) that compiles national K-12 education data by consolidating a number of previously separate federal collections. EDFacts tend to centralize performance and other aggregate data for decision and policy making [10].

2. Standards and Interoperability

The European Telecommunications Standards Institute (ETSI) defined standard in a simple term as a document that provides rules or guidelines to achieve order in a given context. In the context of Information and Communication Technologies (ICT), standards address the needs for interconnection and interoperability [11]. Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged [12]. It is a task of building coherent services for users when the individual

components are technically different and managed by different organizations [13].

For two systems to be interoperable, they must be able to exchange data and subsequently present that data such that it can be understood by a user [14]. However, there can be significant mismatches between the interfaces of various systems that provide similar application functionalities, making interoperation impossible. The reason for this is because developers often implement similar application functionalities in different ways which results to incompatible operation signatures and data types [15]. It becomes necessary to standardise both what is being exchanged (data elements), how to structure it for exchange (record schemas and record syntaxes) and how to actually exchange it (protocol transactions and messages) [16].

Interoperability relies on technical standards which act like a common guide for sharing data between ICT systems. It relies on using agreed data standards and common approaches to connecting systems [17]. Incomplete, unclear standards with poorly specified options can contribute to the biggest single cause of non-interoperability as such standards need to be designed for interoperability from the very beginning [11].

GridWise Architecture Council [18] identified the following approaches and tools towards achieving interoperability:

1. Standardization**:** generically, creating items that are physically and functionally interchangeable.
2. Interchangeability: closely related to standardization, the ability to exchange parts or assemblies without having to alter the item to make the new combination work.
3. Standards adoption: explicit, formal standards set by industry bodies that specify how languages shall be structured and interact. Standards can include articulating engineering, principles, practices, functionality, and performance.
4. Open systems architecture: this is an integrated business strategy using a modular design that defines key interfaces within a system using widely supported, consensus-based standards that are available for use by all developers and users without any proprietary.

2.1. Educational Benefits of Interoperability

The U.S. Department of Education [19] and National School Interoperability Program [17] outline the following as interoperability benefits:

1. Improved access to learning resources and teaching tools.
2. Reliable and secure transfer of educational data.
3. Online assessment and performance monitoring and reporting.
4. Integration of products and services from multiple providers to create a seamless user experience.
5. Access to the same service on a variety of devices.
6. Makes more data and information available to the public.
7. Foster more transparency in the larger educational community.
8. Enhance collaboration with other federal and non-federal agencies, the public, and non-profit and private entities.
9. Improve data quality [1].
10. Reduce the chance of error [1].

2.2. Challenges of Interoperability

The Industry Advisory Council [20] outlines several challenges that are faced in an effort to achieve interoperability and information sharing. They are:

1. Organizational: Achieving consensus on meaning is the most difficult challenge. Agreement on semantics and syntax is difficult to achieve.
2. Architectural: The enterprise architectures of the agencies are not aligned and a process for alignment has not been defined and disseminated to the agencies.
3. Technical: The infrastructure to support interoperability at the service or component and data level is not in place.

3. Integration Architecture

Schmutz, Liebhart and Welkenbach [21] outline four fundamental integration architecture variants. They are:

1. Point-to-Point Architecture: This is a collection of independent systems, which are connected through a network.
2. Hub-and-Spoke Architecture: This represents a further stage in the evolution of application and system integration, in which a central hub takes over responsibility for communication.
3. Pipeline Architecture: Independent systems along a value-added chain are integrated using a message bus.
4. Service Oriented Architecture: The integration of different application to form a functioning whole by means of distributed and independent service calls, which are orchestrated through an Enterprise Service Bus (ESB) and, if necessary, a process engine.

3.1. Service Oriented Architecture (SOA)

Duane, Reitman, Ward and Wilber [22] referred to SOA as an architectural paradigm and discipline that may be used to build infrastructures enabling those with needs (consumers) and those with capabilities (providers) to interact using services across disparate domains of technology and ownership.

In an SOA, resources are made available to other participants in the network as independent services that are accessed in a standardized way [23]. SOAP-based web services are becoming the most common implementation of SOA. However, there are non-web services implementations of SOA that provide similar benefits. The protocol independence of SOA means that different consumers can communicate with the service in different ways [24].

3.2. Web Service

Web service is a software system that is designed to support interoperable machine-to-machine interaction over a network [25]. They make functional building-blocks accessible over standard Internet protocols independent of platforms and programming languages. It depends heavily on the broad acceptance of XML and other Internet

standards to create an infrastructure that supports application interoperability at a level that solves many of the problems that previously hindered such attempts [26].

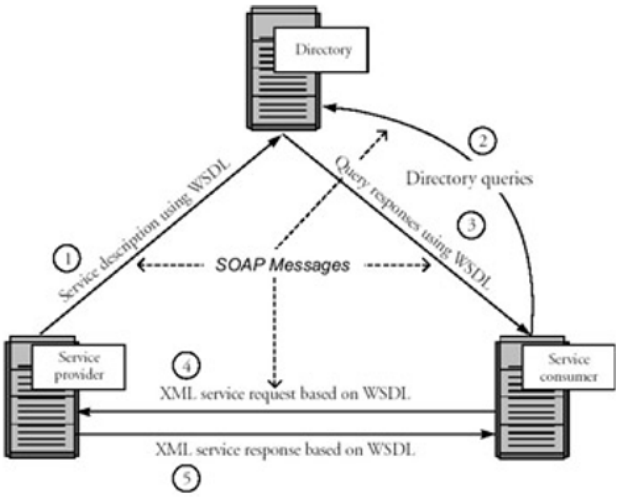

Figure 1. Web service basics. Source: Barry, K. (2003)

Barry [27] used Figure 1 to illustrate the steps involved in providing and consuming a web services as follows:

1. A service provider describes its service using Web Service Description Language (WSDL). This definition is published to a repository of services which could be Universal Description, Discovery, and Integration (UDDI). Other forms of repository could also be used.
2. A service consumer issues one or more queries to the repository to locate a service and determine how to communicate with that service.
3. Part of the WSDL provided by the service provider is passed to the service consumer. This tells the service consumer what the requests and responses are for the service provider.
4. The service consumer uses the WSDL to send a request to the service provider.
5. The service provider provides the expected response to the service consumer.

4. Proposed Framework

4.1. Overview

Software applications developed by different vendors using different platforms can interoperate by adopting a common framework. The proposed framework is based on World Wide Web Consortium (W3C) endorsed XML which is neither platform nor vendor dependent. It defines standards for the common data exchanged among applications in Nigerian universities, NUC and other agencies as well as the protocol for which these applications will interact with one another.

The proposed interoperability framework shown in Figure 2 depicts connection of different universities and other agencies to the Central Integration Server (CIS) which may reside in NUC Data Center or elsewhere.

Adopting the framework will facilitate collaboration among stockholders, enables better public and educational services delivery, allows sharing and reuse of educational data in timely and secure manner.

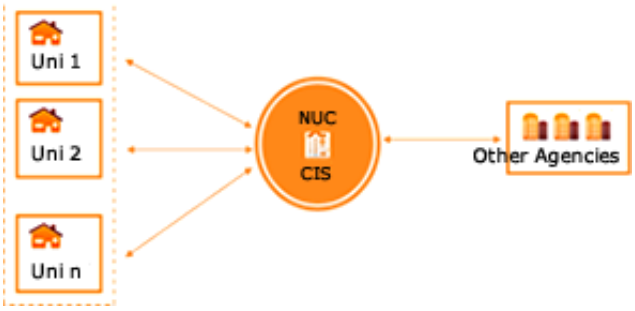

Figure 2. Proposed interoperability framework

Typically, the goal of the framework is to connect SOA enabled application (Such as Student Information System, Library Information System, Hostel Management System, Bursary System and Human Resource Management System) used in Nigerian universities to the CIS using set of standard communication protocol and data exchange for data sharing and access.

4.2. Standardization of Common Education Data

Common education data often used in this paper refers to specific sets of most commonly used educational data elements and objects. Standardising these data means agreeing upon naming convention, formats, definition and technical specification for them. This will support effective exchange of data within and across the university boundary. Table 1 and Table 2 depict some educational data elements and objects respectively.

Table 1. Some common education data elements

Elements	Description
RefId	An object or element identifier
Matriculation Number	A unique numeric or alphanumeric code for identifying a student
Course Code	A six-digit code assigned to a particular course. The first three-digits of the code represent the Course Subject Area and the next three digits identify the course number.

Table 2. Some common education data objects

Objects	Description
StudentBiodata	This object contains information regarding student bio-data
StudentContactInfo	This object contains information regarding the contact of a student
StudentResults	This object contains information related to student results.

4.3. Bridging Data Interoperability Gap

Universities use different information systems developed using varieties of technologies and platforms to meet their information needs. One of the greatest challenges in building web services is therefore creating a common data type system that can be used by a diverse set of programming languages running on a diverse set of operating systems. This is as a result of different programming language providing some basic facility for declaring data types, such as integers, floats, doubles, and strings [28].

Mallalieu and Carriere [29] identified three main data types challenges that need to be resolved to guarantee effective data exchange across platforms. They are:

1. Primitive Data Type: For example, type “String” is a common data type in most programming languages. However, this does not mean they can be exactly mapped at different platforms. Java.lang.String in Java cannot be mapped exactly to System.String in.NET
2. Non-Existing Data Type: For example, how can data type existing in one platform and does not exist in another platform be handled? System. Collections. Specialized. Hybrid Dictionary is a document type in .NET, but not in Java, also Java.util.Vector in Java, but not in .NET.
3. Complex Data Type: How can complex data type made up of nested primitive data type or non-existing data type be used?

Data types have the potential of hampering data interoperability simply because they are not compatible at code level. At the most basic level, implementing data interoperability between platforms involves both platforms understanding a particular data type.

Though several solutions such as serialization exist that allows data exchanged between platforms, the proposed framework uses XML Schema implemented in XML Schema Document (XSD) to resolve data type compatibility by ensuring that platforms agrees on common data type defined by the XSD. Table 3 shows standard definition for student Matriculation Number with it corresponding XML Schema.

Table 3. Standard definition for student matriculation number

Definition	A unique numeric or alphanumeric code assigned to a student by a university
Element ID	0002
Name	Matriculation Number
Alternative Name	MatricNo
Type	String
Length	Maximum 20 character
Format	Alphanumeric
Naming Convention	Three departmental code preceded by numeric code
XML	<xs:simpleType name="MatricNo"> <xs:annotation> <xs:documentation>Usage: Matriculation Number</xs:documentation> </xs:annotation> <xs:restriction base="xs:normalizedString"> <xs:maxLength value="20"></xs:maxLength> </xs:restriction> </xs:simpleType>

4.4. Data Model

This provides XML structure definition for common data elements and objects as shown in Figure 3.

The process begins by first identifying the common data elements and objects that are exchanged among educational applications and the relationships that exist between them. Some of the activities performed in the domain forms the objects. For example student record creation and course registration.

The events that occur on these objects are also identified. Some of these include, student admission change event (like graduation, transfer, withdrawal etc.) or student bio-data update event (like change in residential address).

Data messages that get exchanged as a result of these events are then identified amongst other messages.

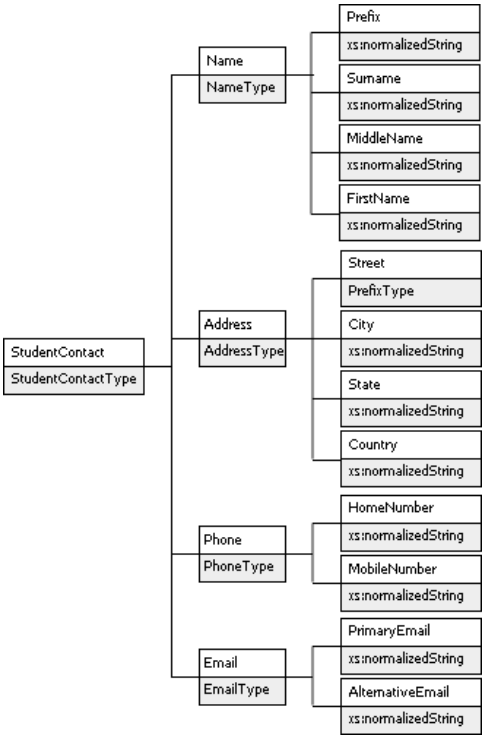

Figure 3. XML data structure of a StudentContact object

```
<StudentContact>
<Name>
<Prefix>Mr</Prefix>
<Surname>Orobor</Surname>
<MddleName>Anderson</MiddleName>
<FirstName>Ise</FirstName>
</Name>
<Address>
<Street>1 Orobor Ise Street, M.M.Way</ Street>
<City>Benin City</ City >
<State>Edo State</ State >
<Country>Nigeria</ Country >
</Address>
<Phone>
<HomeNumber">+2348054001991</ HomeNumber >
<MobileNumber>+2347039190064</ MobileNumber >
</Phone>
<Email>
< PrimaryEmail>
orobor.anderson@fupre.edu.ng </ PrimaryEmail >
< AlternativeEmail>
orobor.ise @gmail.com</ AlternativeEmail >
</Email>
</StudentContact>
```

Figure 4. XML representation of a StudentContact object

4.5. Components of the Framework

1. Software Applications – These are information systems used in the University.
2. XML Schema Document – A document used to defines the standard for common education data including their attributes, types and structure.
3. Adapter – This component serves as an intermediary between the application and CIS.

4. Domain – Where data are generated or managed. It consist of one or more software applications with an adapter used in connecting with the CIS
5. Central Integration Server (CIS) – This act as a hub for central communication. It is a repository of all university information system instances.

4.6. Architecture

It is a hub based architecture that result to web of loosely coupled integration. This provides a powerful and flexible environment that can scale and support SOA based integration. The architecture allows plugin, modification and remover of application without destructing the configuration of others. Figure 5 shows existing systems in isolation and possible integration using the framework.

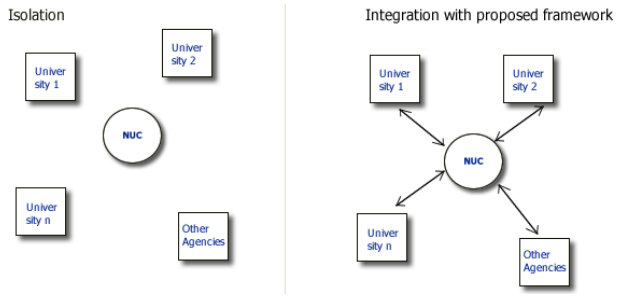

Figure 5. Existing system and proposed framework integration

4.7. How It Works

To exchange data using the framework, the applications in the domain needs an adapter to interact with the CIS. The CIS act as a communication hub. The CIS can reside in the NUC Data Center. See Figure 6 for framework network diagram.

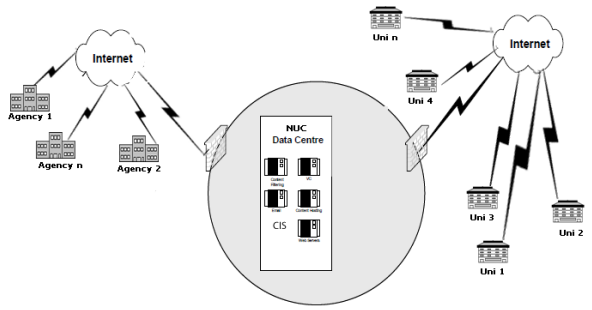

Figure 6. Framework network diagram

The adapter acts as an intermediary between applications and CIS. It enables application send and receive request based on XML message using standard internet protocol like HTTP or HTTPS.

It hides the implementation details of the interoperability mechanism from the connected application.

When data is entered into any application within the participating university, it automatically triggers the appropriate event in the CIS and then performs the corresponding task.

Applications in university can interact with another indirectly by simply calling the instance of that university in the CIS. For example University A can request the transcript of a transfer student from University B by sending the request to CIS. The CIS processes this request using the instance of University B on the server and send back the response to University A.

Corporate organization can query best performing students from each university for scholarship grant.

4.8. Service Security

Protecting the privacy of individuals and maintaining the integrity of educational data involves formidable security enforcement. This is a major concern when providing interoperability. It cut across the ability to authenticate users and determine whether they are authorized to access the data.

Users need to be assured that their interactions with services over the web are kept confidential and the privacy of their personal data is preserved [30].

The open standards communities that created web services developed a number of security standards for web services. It is a reference model that maps the different standards to the different functional layers of a typical web service implementation. Standards at the network, transport and XML security layers are used to secure messages as they are transmitted over the network. The security standards IPsec, SSL/TLS (Secure Sockets Layer/Transport Layer Security), XML Encryption and XML Signature each operate on Simple Object Access Protocol (SOAP) messages at a different level [31].

4.9. Benefit of the Framework

1. One time data entry.
2. Reliable and secure data sharing and re-use.
3. Real-time synchronization of data from vast source.
4. Trusted data sourcing.
5. High data integrity, accuracy and consistency.
6. Increased data accessibility and reporting.
7. Seamless integration of both legacy and new system.

5. Conclusion and Summary

Educational data sharing between universities, NUC and other agencies are essential for both accountability and decision making. However, critical data necessary for this are often trapped in silos simply because universities information systems lack interoperability in its conceptual design.

This paper have proposed a framework that could resolve the heterogeneity that exists in Nigerian universities information systems by leveraging technologies and standards with open, secure and data exchange capabilities. Full implementation of the framework requires organizations active in the education sector such as, universities, NUC, software vendors, industries and other agencies coming together to create common educational data standard. This will enable information systems developed by different vendors using varieties of technologies interoperate.

The framework which is a set of standards, policies, guidelines, procedure and infrastructure will ensure that educational data can be seamlessly shared and re-used securely by stakeholders. It provides a list of common data elements and objects with definition and XML Schema to use during development. The framework is a work towards open standard educational data interoperability

among the ever increasing information systems used in the education sector.

The aims of the framework will not be achieved overnight. The strategy has to be a national initiative, managed as a long-term project and must be genuinely embraced and supported by stakeholders.

References

[1] L. Collins, L. Fruth, M. Sessa and E. Laird, "The Right Data to the Right People at the Right Time: How Interoperability Helps America's Students Succeed", PESC White Paper, 2007. Available at: http://www.pesc.org/library/docs/about_us/whitepapers/DQCBriefingonInteroperability062007.pdf. (Downloaded: 24 July 2014)》

[2] J. Piper, "Industry Efforts to Increase Building Systems Interoperability Deliver New Information Sharing Capabilities", 2005. Available at: http://www.facilitiesnet.com/buildingautomation/article/Freedom-of-Information--2637. (Accessed: 7 July 2014).

[3] J. Stevenson and B. Ruddock, "Moving Towards Interoperability: Experiences of the Archives Hub", Ariadne, 2010. Available at: http://www.ariadne.ac.uk/issue63/stevenson-ruddock. (Accessed: 7 July 2014).

[4] A. Adekunle, "NUC out with online accreditation portal", Vanguard, 2012. Available at: http://www.vanguardngr.com/2012/09/nuc-out-with-online-accreditation-portal/. (Accessed: 2 July 2014).

[5] Nigeria University Commission, "NUC Launches Maiden Accreditation Portal", NUC Bulletin, 7(37), 2012, pp. 1-2.

[6] Nigeria University Commission, "NUC Holds Workshop on NUS Management Portal", NUC Bulletin, 8(14), 2013, pp. 1-2.

[7] School Interoperability Framework. Available at: http://www.sifinfo.org/us/index.asp. (Accessed 2 July 2014).

[8] National Schools Interoperability Program, "Interoperability in education, Australia", 2014. Available at: http://www.nsip.edu.au/systems-interoperability-framework. (Accessed: 2 September 2014).

[9] Ed-Fi Alliance. Available at: www.ed-fi.org. (Accessed 2 September 2014).

[10] U.S. Department of Education, "The EDFacts Initiative, 2010. Available at: http://www2.ed.gov/about/inits/ed/edfacts/index.html. (Accessed: 7 July 2014).

[11] ETSI World Class Standard, "What are standards?", 2014. Available at: http://www.etsi.org/standards/what-are-standards**.** (Accessed 2 September 2014).

[12] IEEE, IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries, New York, NY. 1991.

[13] A. Willium, "Thoughts about Interoperability in the NSDL", 2000. Available at: http://www.cs.cornell.edu/wya/papers/NSDL-Interop.doc. (Downloaded: 24 July 2014).

[14] Healthcare Information and Management System Society, HIMSS Dictionary of Healthcare Information Technology Terms, Acronyms and Organizations, 2nd edn., 2010, p190.

[15] Y. Bromberg, P. Grace, L. Reveillere and G. Blair, "Bridging the Interoperability Gap: Overcoming Combined Application and Middleware Heterogeneity," 12thIFIP/ACM/USENIX International Middleware Conference. pp. 390-409, 2011.

[16] G. Janifer, "Internet, Interoperability and Standards: Filling the Gaps", 2012. Available at: http://www.niso.org/publications/white_papers/wp-gatenby. (Accessed: 2 July 2014).

[17] National Schools Interoperability Program, "Why interoperability?", 2014. Available at: http://www.nsip.edu.au/interoperability-in-education. (Accessed: 2 September 2014).

[18] GridWise Architecture Council, "Reliability Benefits of Interoperability", 2009. Available at: http://www.gridwiseac.org/pdfs/reliability_interoperability.pdf. (Downloaded: 7 July 2014).

[19] U.S. Department of Education, "Digital Systems Interoperability", 2010. Available at: http://www.ed.gov/open/plan/digital-systems-interoperability. (Accessed: 7 July 2014).

[20] Industry Advisory Council, "Interoperability Strategy Concepts, Challenges, and Recommendations", Industry Advisory Council Concept Level White Paper, 2003. Available at: http://www.eprocesssolutions.com/CMS/documents/InteroperabilityStrategy.2003-03-06.doc. (Downloaded: 2 July 2014).

[21] G. Schmutz, D. Liebhart and P. Welkenbach, Service Oriented Architecture: An Integration Blueprint, Packt Publishing, 2010.

[22] N. Duane, L. Reitman, J. Ward and J. Wilber, "Service Oriented Architecture (SOA) and Specialized Messaging Patterns", Technical white paper., 2007. Available at: http://www.adobe.com/enterprise/pdfs/Services_Oriented_Architecture_from_Adobe.pdf (Downloaded: 24 July 2014).

[23] P. Helmut, "Service-Oriented Architecture (SOA) vs. Component Based Architecture", 2006. Available at: http://petritsch.co.at/download/SOA_vs_component_based.pdf.(Downloaded: 2 July 2014).

[24] R. Margaret, "Service-Oriented Architecture (SOA)", 2008. Available at: http://searchsoa.techtarget.com/feature/ service-oriented-architecture. (Accessed: 2 July 2014)

[25] World Wide Web Consortium, "W3C, Web Services Architecture", 2004. Available at: http://www.w3.org/TR/ws-arch.(Accessed: 8 August 2014.

[26] Microsoft, "XML Web Services Overview", 2005**.** Availableat: http://msdn.microsoft.com/en-us/library/w9fdtx28%28v=vs.80%29.Aspx. (Accessed 2 July 2014).

[27] K. Barry, Web Services and Service-Oriented Architectures: The SavvyManager's Guide, San Francisco:Morgan Kaufmann, 2003

[28] E. Cerami, Web Services Essentials: Distributed Applications with XML-RPC, SOAP, UDDI & WSDL, O'Reilly, 2002.

[29] T. Mallalieu and J. Carriere, Application Interoperability: Microsoft .NET and J2EE.Microsoft Press, 2004, pp. 14-15.

[30] E. Bertino, L. Martino, F. Paci and A. Squicciarini, Security for Web Services and Service-Oriented Architectures, Springer-Verlag Berlin Heidelberg, 2010.

[31] A. Singhal, T. Winograd and K. Scarfone, "Guide to Secure Web Services, National Institute of Standards and Technology Special Publication 800-95", 2007, pp. 12-13.