COMPUTER-BASED DATA MANAGEMENT MODEL FOR CHEMISTRY RESEARCH IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

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ABSTRACT

This study developed a computer-based data management model for chemistry research in federal universities of technology (FUTs) in Nigeria. There are five FUTs in Nigeria namely: FUT Minna, FUT Akure, FUT Owerri, ATBU Bauchi and MAUTECH, Yola. These specialised universities were selected because they have similar structure in terms of funding and academic programmes. A field of study found in all the federal universities of technology in Nigeria, and which is germane to this study, is Chemistry. The study aimed at determining research data management practices and perceptions of chemists and to further develop a computer-based data management model for use in chemistry. A data management model is a system that guide researchers on the relevant data items and information that needs to be preserved all through the research lifecycle. Four research objectives and questions guided the study. The first objective was to understand the existing research data management practice of chemists, second objective developed a software prototype that can assist in research data management based on chemists' existing research workflow, third objective was for technology acceptance testing of the developed software, while the fourth objective suggested a framework for implementation of research data management services by libraries in FUTs in Nigeria. The study adopted the exploratory research design using mixed methods of qualitative and quantitative data gathering and analyses. Forty (40) chemists and fifteen (15) heads of libraries, Information and Technology Service (ITS) units and research offices across the five FUTs in Nigeria participated in the study. Interview schedule, record inspection, observation technique, and copies of questionnaire were used to gather data. Qualitative data analysis was done using thematic explanation building techniques and *Provalis Qualitative Data Analysis* software; while median and Kendall's Tau-b Correlation Coefficient was used to analyse quantitative data. Java programming language and MySQL database management system was used to develop the frontend and back end of the software prototype respectively. The developed software named: Chemistry Research Data Management System (ChRDMS) was subjected to users and technology acceptance testing using the Unified Theory of Acceptance and Use of Technology (UTAUT) model. Findings revealed that chemists in Nigeria are yet to incorporate appropriate research data management practice during their research processes. However, their behavioural intention towards use of the developed computer-based research data management prototype is significant as they found the software relevant to their research workflow and easy to learn and use. Research experience of chemists was also found to be a major reason for the acceptance and use of the ChRDMS. The study therefore, concluded that libraries in FUTs in Nigeria should as a matter of urgency, roll out research data management services using the implementation framework proposed by this study.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Information is popularly defined as processed data on which decisions and actions are based. According to Oyedum (2006), information can be generated in various ways: oral, written; and from media such as radio, television, newspapers; online blogs, personal experiences, books, journal and magazine articles, expert opinions, encyclopaedias, and web pages. The Virginia Tech University Libraries gave the different sources of information as: primary, secondary, and tertiary. Primary sources allow researchers to get as close as possible to original ideas, events and empirical researches. Such sources may include creative works, first hand or contemporary accounts of events and the publication of the results of empirical observations or research. Examples of primary sources of information include: diaries, interviews, letters, and original works of art, photographs, speeches and works of literature. Secondary sources include: analysis, review, or summarise information in primary resources or other secondary resources. The most important feature of secondary sources is that they offer an interpretation of information gathered from primary sources. Examples of secondary sources are: biographies, dissertations, indexes, abstracts, bibliographies (used to locate a secondary source), journal articles, and monographs. A tertiary source presents summaries or condensed versions of materials, usually with references back to the primary and/or secondary sources. They can be a good place to look up for facts or get a general overview of a subject, but they rarely contain original material. Examples of tertiary sources are: dictionaries, encyclopaedias and handbooks.

An indisputable avenue of accessing information either from primary, secondary or tertiary sources is research. Succinctly, research according to Madu & Dike (2012) is a systematic enquiry towards answering a question or unravelling mysteries around a particular phenomenon. Research outputs are results of such enquiries accepted within a scientific community so as to better human life and the society. Research forms the basis for academic productivity, which is seen as the measure of the required output expected of an academic staff (Madu& Dike, 2012). The Research Experience and Applied Learning (REAL) Centre of the University of California in San Diego defined research as a systematic inquiry that investigates hypotheses, suggests new interpretations of data or texts, and poses new questions for future research to explore. Research consists of asking a question that nobody has asked before; doing the necessary work to find the answer; and communicating the knowledge acquired to a larger audience. A well conducted research will project not only the image of the researcher but also of the institution the researcher is affiliated to. Furthermore, academic research is considered to be efficient and socially valuable if it offers solution to real problems that confront companies and/or individuals (Milena *et al.*, 2008). Most researches are achieved through collating and analysing recorded data over a period of time.

Data are collection of facts, concepts, numbers, words, measurements, observations, or instructions in a formalised manner which should be suitable for communication, interpretation, or processing by human or electronic machine. Data that are collected and presented in a form that the computer system can understand are referred to as digital data. Data vary across disciplines: they can be numeric, textual, audio, video, and graphic. They can also be samples (such as Deoxyribonucleic acid (DNA), blood), physical collections (plant specimens, animal samples), software codes and programmes, algorithms, geospatial data, databases, modules, reports, experimental observations, survey results and interview transcripts, instrument measurements, laboratory notebooks, to mention but a few. Hence, data generated during the conduct of any research for the purpose of sharing and reuse is known as research data.

Research data cover a broad range of types of information and digital data can be structured and stored in a variety of file formats. Pienaar and VanDeventer (2015) defined research data as the recorded factual material commonly accepted in the scientific community as necessary to validate research findings. They are data collected, observed or created for the purpose of analysis to produce and validate original research results. Research data can be in the form of facts, observations, images, computer programme results, recordings, measurements or experiences on which an argument, theory, test or hypothesis, or another research output is based (Pienaar andVanDeventer, 2015). Research data are valuable products of the scientific enterprise that historically have not been well preserved or archived. International sponsors and scientific journals are now encouraging or requiring sound data management and data sharing before granting fund or accepting article for publication indicating how critical effective data management practices are to the scientific research processes (Thoegersen, 2015; Schubert *et al.;*2013 and Sheehan, 2016).

Research Data Management is a standard part of good research practice offering a lot of benefits to the society, research funders and the research community. Jones *et al.* (2013) gave the Digital Curation Centre (DCC) definition of Research Data Management (RDM) as “the active management and appraisal of data over the lifecycle of scholarly and scientific interest”. It could help researchers by potentially increasing efficiency, saving time and resources and boosting the impact and visibility of their work through openness and transparency. Research data management refers to activities and practices such as planning of data, documenting, formatting, storing, anonymising, and controlling access that support long-term preservation and use of data.

In the same vein, Smith (2014) observed that the challenge of how to effectively manage research data affects all scientists and researchers within and across multiple domains. The study observed further that most researchers struggle unsuccessfully with storage and management of their burgeoning volume of documents and datasets that they need and that result from their work. The consequence of this is that rising accumulation of useful findings might be lost or unavailable when conducting future research. There is, therefore, the need to incorporate a good data management practice throughout the research workflow.

This could be done efficiently by: establishing how data would be collected, documented, organised, managed, and preserved at the beginning of a research project. Strasser *et al*. (2015) opined that the goal of data management is to produce self-describing datasets that would be discoverable and usable in future. Research data also will be easier to find, use, and analyse, and it will be easier for collaborators to understand and use the data. On the long run, following good data management practices means that scientists not involved in the project can find, understand, and use the data in the future; also, by documenting data and recommending appropriate ways to cite the data, researchers can be sure to get credit for their data products and their use. This will ensure that research findings remain 'alive' for as long as the accompanying research data is preserved.

Universities and other allied institutes by the mandates of their establishment are repositories of research outputs and are expected to keep research findings alive.They are equally charged with the responsibility of conducting problem-targeted researches aimed at improving human lives and the society. According to Oyedum *et al.* (2014), universities are established for the purpose of reading, learning, research and community development. They are regarded as institutions where knowledge is transferred from one individual to another for the sole aim of manpower development in the nation. This is achieved by encouraging research activities and dissemination of research findings through publications, and establishing libraries to serve as a store house of knowledge where various information (and data) is stored for preservation, access and use.

Research is not complete until it comes out in visible or fixed formats like publication. Publication is one of the core requirements for the promotion of academic staff in a university system. In academic circles, 'publish or perish' is the popular slogan (Egwunyega, 2008). Publication is used for promotion and for assessing impact of academic staff on the university system. The implication of this is that academic staff, albeit other assigned duties in the department, must strive to publish certain number of articles in acceptable journals in order to be promoted. Researchers are usually advised to publish in journals with high impact factors and web visibility.

One of the important criteria for accepting manuscripts for publishing in high impact factor journals is availability of research data (Vines *et al.*,2013). In order to achieve this, a number of journals have incorporated into their requirements a Data Archiving Policy (DAP) or Joint DAP, which they expect that authors adhere to before their manuscripts are accepted for publication. The Joint Data Archiving Policy or JDAP, as presented in Vines *et al.*(2013) stated that "[Journal X] requires, as a condition for publication, that data supporting the results in the paper should be archived in an appropriate public archive”. A public archive can be a repository managed by an institution through the library or a public archive.

Library is a system comprising a collection of recorded knowledge, retrieval devices, users and library personnel, all associated in such a way as to maximise the knowledge transfer process (Oyedum, 2006). There are different types of libraries each existing to service a defined user community. There are public, academic, special, private and national libraries. Academic libraries are libraries found in institutions of higher learning. Collections in academic libraries are available in both print and non-print formats covering different areas of human knowledge. Part of the objectives of an academic library is to make relevant, detailed and current information available whenever it is requested for by users. Another objective of the academic library is to preserve and make available intellectual contents emanating from the institution it is serving. Traditionally, recorded knowledge in the form of print and non-print materials are required to be deposited in the library for long-term preservation and access. The curators of the deposited information-bearing materials are the librarians.

Librarians are professionals responsible for managing, preserving, and creating access to stored information resources in the library. They have expertise in the use of various information retrieval tools and answering of reference queries with the aim of satisfying users’ information needs. These information retrieval tools are: catalogue cards, bibliographies, abstracts, encyclopaedias and indexes. A key function of a librarian is to support research. Librarians are well placed to support researchers using their relevant skill sets such as: referencing, information retrieval, database searches and preservation and dissemination of research outputs. Good existing relationships with researchers also make it easier to provide research support and related services. The specific role of librarians (and libraries) in Research Data Management (RDM) are in the areas of: advocacy, support services, data literacy training, data citation, managing data repositories, and making a case to university management on the importance of RDM to researchers and institutions.

A new dawn in terms of ease, convenience, quality, cost effectiveness, result-oriented and wider coverage has been introduced to research with the advent of Information and Communication Technologies (ICT) and its associated enabling devices. There are various ICT tools and online services such as: computers, telecommunication equipment, application software, online reference services, online public access catalogue, and electronic databases that can be used in the library. Libraries now subscribe to electronic databases that contain millions of published articles around the world. Online Public Access Catalogue (OPAC) is another useful library service that assists users in accessing the holdings of a library from wherever they are.

Universities, research institutes and other institutions of higher learning contribute immensely to the growth and development of nations of the world. Taking a cursory look at Nigeria, a study by Asiabaka (2006) assessed the relevance of Research and Development (R&D) programmes of Nigerian universities to national development. The study concluded that R&D programmes of universities are vital to national development and recommended the need for a well-articulated and focused R&D agenda in the Country. In response to the need for research geared towards national and societal developments, the Federal Government of Nigeria, through the National Universities Commission (NUC) has accredited about 195 universities covering various areas of science, technology, engineering and management (STEM) (NUC, 2021). Five of these universities are specialised universities of technology spread across the geo-political zones of Nigeria. These federal universities of technology have similar structure in terms of funding and academic programmes. A field of study found in all the federal universities of technology in Nigeria, and which is germane to this study, is Chemistry.

Put concisely, chemistry is the study of matter and energy and the interaction between them. It is sometimes referred to as ‘central science’ because it connects other sciences to each other, such as biology, physics, geology and environmental science (Helmenstine, 2016). Chemistry helps individuals understand how and why substances combine or separate to form other substances, and how substances interact with energy. According to Bagley (2014), there are five main branches of chemistry, each of which has many areas of study: analytical chemistry- uses qualitative and quantitative observation to identify and measure the physical and chemical properties of substances; physical chemistry- combines chemistry with physics; organic chemistry- specifically studies compounds that contain the element carbon; organic chemistry is known as the “Chemistry of Life” because all of the molecules that make up living tissue have carbon as part of their makeup; inorganic chemistry- studies materials such as metals and gases that do not have carbon as part of their makeup; biochemistry is the study of chemical processes that occur within living organisms.

Researches in chemistry assist individuals to understand the society and the world by conducting experiments aimed at solving problems and making the world a better place to live. Nature, an interdisciplinary scientific journal ranked as the world’s most cited scientific journal and widely regarded as one of the few remaining academic journals that publish original research across a wide range of scientific fields, published a study on the top 100 most cited research of all time. The study conducted by VanNoordeen *et al.* (2014) revealed that an article published in the Journal of Biological Chemistry has the highest number of citations out of all the papers in the fields under study. This distinction goes to a 1951 paper by US Biochemist Oliver

Lowry and colleagues. The article is on determining the amount of protein in a solution. It is also interesting to note that the top five positions were all taken by Chemistry-related researches.

All researches conducted generate their own data. Effectively managing the research data for reuse and long term preservation are challenges especially to chemists. Developing a data management model that can suit existing workflow of chemists becomes necessary. A model is a representation of an abstract idea to make it tangible. It can be graphical, mathematical (symbolic), physical, or verbal representation or simplified version of a concept, phenomenon, relationship, structure, system, or an aspect of the real world. In research, a model shows relationships between variables and/or concepts with the use of arrows for directions. An established model can be used as a guide to follow in carrying out a task or activity. This study hopes to develop a computer-based data management model for chemistry research in the form of a software prototype using a programming language of choice. Nonetheless, it is not enough to develop a model, an acceptance testing of the model must be conducted to determine whether the technology will be accepted and used by the intended recipients.

Acceptance means agreeing or receiving something that is offered. Full acceptance is demonstrated by the actual use of what is accepted and manifesting same in the recipient's behaviour. Acceptance testing is done to determine whether a developed system meets the required specification. This is also a way of generating feedbacks on the developed system for improvement. In computer software testing, the International Software Testing Qualifications Board (2010) defines acceptance as "formal testing with respect to user needs, requirements, and business processes conducted to determine whether a system satisfies the acceptance criteria and to enable the user, customers or other authorized entity to determine whether or not to accept the system". For this study, technology acceptance will be tested using the Unified Theory of Acceptance and Use of Technology (UTAUT) model to study chemists' behavioural intention to use the developed data management prototype.

From the foregoing discussion, it is clear that federal universities of technology in Nigeria are vital to the nation's development especially as Nigeria strives to become one of the World's best economies through innovations and researches in Science, Technology, Engineering and Mathematics (STEM). It was also observed that research is needed by every society for breakthroughs and improving the activities observed in industries and society. From literature and observation, it is clear that data management practice is inadequate among researchers in Nigeria and this has had detrimental effect on the visibility and originality of indigenous researches (Thomson, 2016). Poor data management has also led to irrecoverable loss of data and information (Kuula & Borg, 2008; Burnham 2013; Gonzalez & Pedro, 2015). This situation could be salvaged by incorporating effective data management practice throughout the research workflow. This study seeks to provide a workable solution to data management in chemistry researches in federal universities of technology (FUTs) in Nigeria.

1.2 Statement of the Research Problem

Appropriate research data management practice ensures that underlying research data necessary for validating and supporting research findings are available and usable by the scientific community. The practice also prevents irrecoverable loss of data and information in the long run. Research data, as an integral part of a research, are being required by impact-factor journals to be submitted alongside articles before they are accepted for publication. This is to enable research findings to be verifiable and reusable. Government and international funders also see research data as a return-on-investment because another user can re-purpose and reuse the research data. Giving access to research data for reuse by secondary users ensures that new researches are novel and not re-inventing the wheel or duplicating previous researches.

Scientific researches involve conducting experiments that are characterised by generation of large data. Chemistry, as a scientific field of study, involves various stages of experiments each of which generates distinct research data. Managing these research data becomes necessary and challenging especially now that it is being required to be submitted alongside articles for publication in impact factor journals and it is also a requirement for applying for international research grants and funding. Preliminary literature reviewed showed that there is no research data management model that can assist researchers in developing countries, especially Nigeria, to effectively manage data generated across the research lifecycle. There is also no computer-based data management system developed for chemists in Nigeria that can suit indigenous research environment.

It is against this backdrop that this study seeks to determine the data management practices of chemists in federal universities of technology in Nigeria with a view to gathering requirements for developing a computer-based data management model suitable for Nigerian research environment and to equally conduct an acceptance testing of the developed data management model.

1.3 Aim and Objectives of the Study

The aim of this study is to develop a computer-based data management model and conduct an acceptance testing of the model in chemistry research in federal universities of technology (FUTs) in Nigeria.

The following objectives guided the study:

1. determine the data management perception of chemists in FUTs in Nigeria with a view to gathering requirements for developing a data management model;
2. develop a computer-based data management model for chemistry research in FUTs in Nigeria using the evolutionary prototyping;
3. conduct technology acceptance testing of the computer-based data management model using the unified theory of technology acceptance and use model;
4. propose a framework for incorporating research data management services by libraries in FUTs in Nigeria.

1.4 Research Questions

The study will seek to provide answers to the following research questions:

1. what arethe data management practises of chemists in FUTs in Nigeria?
2. what computer-based data management model suits the existing research workflow of chemists?
3. what is the behavioural intention of chemists towards acceptance and use of the developed computer-based research data management model?
4. how can libraries in FUTs in Nigeria incorporate research data management services for enhanced chemistry research?

1.5 Research Hypotheses

The Unified Theory of Acceptance and Use of Technology (UTAUT) was adopted for assessing technology acceptance of the developed data management prototype by

Chemists in FUTs in Nigeria. These core constructs are Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC). There are also control variables that might affect or moderate these core constructs. These control variables are "gender", "age", "experience", and "voluntariness of use".

The null hypotheses were formulated and tested at 0.05 level of significance:

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by "social influence";

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by "facilitating conditions";

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

1.6 Justification of the Study

The availability of an institutional data repository not only enhances the global visibility of the institution but also demonstrates that the academic environment is fit to support high quality research. Institutional digital repositories hold great promise for preservation of materials, sharing of resources, and enable more meaningful and fruitful researches to be conducted through access to relevant data and literature (Umar *et al.*, 2014). The existence of services and support for research data management (RDM) is another key component of a strong research environment. Research data (also known as datasets) are deposited in institutional repositories same way as other intellectual contents emanating from the university such as published articles and inaugural lectures. Librarians, using their relevant skill sets, are responsible for the description, preservation, and creation of access to these datasets using appropriate metadata schemes. Metadata refers to unique description of data in a way that it is easily identified among other datasets.

However, before research data are deposited in the library and stored in an institutional repository, data owners (authors) must have done some form of ‘data cleaning’ through appropriate data management practice so that the final product (dataset) would be one that can be ultimately used by the librarian for curation and long term preservation. Developing a computer-based data management model that fits into existing workflow of researchers would help not only the researchers, but also librarians and the university as a whole.

RDM defines a new role of offering library service and support to researchers. The role of the library in achieving this is very fundamental, especially in the area of training and advisory services. Librarians can perform this role by organizing regular meetings with research teams (i.e. embedded librarians) in order to provide guidance related to data management, preservation, and other related issues. This will provide an opportunity for librarians to become effective members of research teams and improve research output thereby achieving the research-support role of the university library.

Federal universities of technology are selected for this study because of their core mandate of ensuring sustainable development of Science and Technology in Nigeria.

Chemistry on the other hand is a central science relevant to all science and technology related fields and offered in all the FUTs under study.

1.7 Significance of the Study

The study will be of benefit in the following ways: it will expose chemists to research best practices around the world and guide them on how to effectively manage their research data for long-term preservation and reuse.The study will open new and trending library and information services offered by librarians around the world and ensuring that generated datasets are in a format that the library can work with.

Findings of this study can be used by Research Data Management stakeholders such as: the university management, Information Technology Service (ITS) unit, Research Office and Library, in determining the best way of supporting research through provision of management systems for research data management. This will in the end help cut cost by ensuring that only novel and problem-solving researches are funded and commercialised.

Ultimately, the visibility and reputability of the university and its researchers will be improved with a higher ranking amongst counterparts in Africa and around the world.

1.8 Scope of the Study

This study seeks to develop a computer-based data management model for chemistry research in FUTs in Nigeria.These FUTs in Nigeria are in four out of the six geopolitical zones inNigeria. They are: the Federal University of Technology, Minna, Niger State (North Central); Federal University of Technology Akure, Ondo State (South West); Federal University of Technology, Owerri, Imo State (South East); Modibbo Adama University of Technology, Yola (North East) formerly Federal University of Technology, Yola; and Abubakar Tafawa Balewa University, Bauchi

(North East). While there are two federal universities of technology in the North East, there are none in North West and South South. This study therefore appeal to the Federal Government of Nigeria to establish a specialized federal university of technology in the remaining two zones in Nigeria.

By chemists, we mean academic staff with a doctoral degree as well as lecturers undergoing a doctoral training. This is to ensure that data management practice of only academic staff with relevant research experience is studied. Research experience include: number of supervised students' projects, theses and dissertations, conference paper presentations, books and journal publications, inaugural lectures, public lectures and patented research work.

The study covered researchers and lecturers in chemistry (also referred to as chemists), irrespective of the options they belong to. This study is however, limited to the research data management practices of chemists and not on chemistry as a discipline *per se*.

1.9 Overview of Federal Universities of Technology in Nigeria (FUTs)

National Universities Commission (NUC, 2021) gave the following registered FUTs in Nigeria:

1.9.1 Federal University of Technology, Minna, (FUT Minna) Niger State

The Federal University of Technology, Minna is a federal government owned university in Nigeria. It was established on 1st February, 1983. The objective for its establishment is to give effect to the Nation's drive for the much-needed self-reliance in Science, Engineering and especially Technology. It is a specialized university of technology. The university has nine Schools namely School of Engineering and Engineering Technology, School of Agriculture and Agricultural Technology, School of Physical Sciences, School of Life Sciences, School of Information and Communications Technology, School of Entrepreneurship and Management Technology, School of Infrastructure, Process Engineering and Technology, School of Environmental Technology, School of Science and Technology Education, and a postgraduate school.

Chemistry department is housed in the School of Physical Sciences alongside Statistics, Physics, Mathematics, Geology, and Geography. The available options in chemistry are polymer, analytical, organic, industrial and nanochemistry (Source: www.futminna.edu.ng).

1.9.2 Federal University of Technology, Akure, (FUTA) Ondo State

Federal University of Technology, Akure was established in 1981. The university has grown tremendously, stretching its academic disciplines and research across seven different schools and over forty academic departments. The vision of the university is to be a world class University of Technology and a centre of excellence in training, research and service delivery, while the mission is to promote technological advancement by providing conducive environment for research, teaching and learning engenders development of products that are technologically oriented, self-reliant and relevant to society. There are nine schools and a postgraduate school. School of Agriculture and Agricultural Technology, School of Engineering and Engineering Technology, School of Earth and Mineral Sciences, School of Environmental Technology, School of Management Technology, School of Health and Health Technology, School of Computing, School of Science, and School of Postgraduate Studies.

Chemistry department in FUTA is housed in the School of Sciences alongside other departments like Biochemistry, Biology, General Studies, Computer Science, Mathematical Sciences, Microbiology, Physics and Statistics. The available options in chemistry are analytical, industrial, environmental and biogeochemistry (Source: www.futa.edu.ng).

1.9.3 Federal University of Technology, Owerri, (FUTO) Imo State

FUTO, as the oldest university of technology in Nigeria, was established in 1980 by executive fiat with the composition and appointment of the first provisional Council by Nigeria's First Executive President, Shehu Shagari. It became the first of three such Universities set up by the Federal Government of Nigeria who sought to establish a University of Technology in each geo-political region and particularly in a state which did not have a conventional university. There are ten schools and a postgraduate school. School of Agriculture and Agricultural Technology, School of Basic Medical Sciences, School of Biological Sciences, School of Engineering and Engineering Technology, School of Electrical Systems Engineering Technology, School of Environmental Science, School of Health Technology, School of Management Technology, School of Information and Communication Technology, and School of Physical Sciences.

The department of chemistry is housed in the School of Physical Sciences alongside Biology, Computer Science, Physics, Mathematics, Science Laboratory Technology and Statistics (Source: www.futo.edu.ng)

1.9.4 Modibbo Adama University of Technology, (MAUTECH) Yola, Adamawa State

Modibbo Adama University of Technology, Yola formally known as Federal University of Technology, Yola (FUTY) Adamawa State, Nigeria was established in 1981 by the Federal Government of Nigeria to provide the much needed technologically skilled manpower for the nation. It is one of the Federal Universities recognized by the National Universities Commission (NUC) to offer Bachelor's, Master's and Doctorate degrees in different fields of Science and Technology. The University runs undergraduate and postgraduate programmes in seven schools namely: School of Agriculture and Agricultural Technology (SAAT), School of Environmental Science (SES), School of Management and Information Technology (SMIT), School of Physical Sciences (SPAS), School of Engineering and Engineering Technology (SEET), School of Technology and Science Education (STSE) and School of Postgraduate Studies (SPGS).

The department of chemistry is housed in the School of Pure and Applied Sciences. Other departments in the School are Biochemistry, Biotechnology, Biological Sciences, Computer Science, Mathematics, Statistics and Operations Research, Science Laboratory Technology, Geology, Physics, Plant Science, Zoology. The available options in chemistry are pure and industrial chemistry (Source: www.mautech.edu.ng).

1.9.5 Abubakar Tafawa Balewa University, (ATBU) Bauchi, Bauchi State

The Abubakar Tafawa Balewa University, ATBU, Bauchi was established in 1980 as the Federal University of Technology (FUT), Bauchi, located in the North Eastern part of Nigeria. The vision of the university is to become a centre of excellence for the creation, transfer and application of scientific knowledge for the advancement of mankind in a friendly, interactive and multi-cultural environment. While the mission is to provide relevant and high quality education and prepare individuals for work, leadership and meaningful life, through promotion of research, teaching, development and testing of ideas in order to advance understanding and quality of life.

The name of the college was in honour of the first Prime Minister of Nigeria, Late Sir Abubakar Tafawa Balewa. In 1988, it was de-merged from the Ahmadu Bello University and regained its autonomy as a full-fledged university. The university has seven faculties and a postgraduate school. Faculty of Agriculture and Agricultural Technology, Faculty of Engineering and Engineering Technology, Faculty of Environmental Technology, Faculty of Management Technology, Faculty of Technology Education, and Faculty of Science, and Faculty of Management Sciences.

Department of Chemistry is housed in the Faculty of Sciences alongside Mathematical Sciences, Biological Sciences, Geology and Physics. The available options in Chemistry are analytical, inorganic, organic, physical, industrial, and polymer (Source: www.atbu.edu.ng).

1.10 Operational Definition of Terms

The following terms are operationally defined as used in this study:

Acceptance: attitude of chemists in FUTs towards adoption and use of the developed data management model.

Chemistry: a scientific field of study on which this study is based.

Curation: management activities involved in ensuring that research data generated in chemistry researches are properly described, preserved for long-term access and discoverable on the Web.

Chemist: academic researchers found in chemistry departments in FUTs in Nigeria.

ChRDMS: the chemistry research data management software prototype developed by this study.

Dataset: a well-organized research data ready for reuse and repurposing.

Effort expectancy: the degree of simplicity associated with the use of the ChRDMS software prototype.

Facilitating conditions: the degree to which chemists believe that an organizational and technical infrastructure exist to support the use of the developed ChRDMS prototype.

FUTs: all federal universities of technology in Nigeria namely: FUT Minna; FUT Akure; FUT Owerri; Modibbo Adama University of Technology, Yola; and Abubakar Tafawa Balewa University, Bauchi.

Impact Factor: is the measure of popularity of an article among researchers in a scientific community.

Journal: a serial publication containing accepted articles from different authors on a specific subject scope.

Model: a research data management prototype developed in this study to guide researchers towards achieving a research goal.

Open access: allowing other researchers to use your research work with little or no barrier to access.

Performance expectancy: the degree to which chemists believe that using the ChRDMS software prototype would improve his or her job performance.

RDM: means research data management. That is, planned activities by chemists during a research process aimed at preserving and granting access to research data.

RDMS: research data management system. The prototype software system developed by this study. Also known as ChRDMS.

Research data: all kinds of raw facts generated in the course of finding answers to questions. It is organized data that can be reused and validated for future research.

Social influence: the degree to which chemists perceive that others believe he or she should use the ChRDMS software prototype.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual framework

2.1.1 Research and national development

Research is a fundamental practice among academicians in institutions of higher learning. It involves the systematic search for unknown or verifying what is known towards expanding the frontiers of human knowledge in a particular context. With the advent of self-rule in Nigeria and bearing in mind the importance of research activities in nation building, the government took a bold step to institutionalize research by establishing the Cocoa Research Institute at Ibadan, Nigerian Institute for Oil Palm Research near Benin, and the Veterinary Research Institute, Vom near Jos.

The greatest focal point of research activities in Nigeria is in educational institutions at the tertiary level (Egwunyenga, 2008). This is because research is made compulsory for both lecturers and students either by job description or by prescribed programmes of study. Every graduating student at every level is actively involved in research activities for the fulfilment of partial requirement for the certificate/degree being sought or as terminal thesis or dissertation. These research activities are under the supervision of academic members of staff in the relevant department. Academic staff also conducts research aimed at promotion and in fulfilling the 'publish or perish' syndrome. It is therefore expected that volumes of research reports from graduating students and academics should improve the nation by moving it from poverty to greatness. But the reverse is the case as the deposited research reports are left to gather dust in the various departmental offices. Copies deposited in the library are rarely consulted as the library is also witnessing dwindling patronage.

For the academics, once their researched works are published in reputable journals, copies are kept only to be produced for appraisal for necessary promotion. What becomes of the findings does not really matter anymore (Egwunyenga, 2008). The general feeling is that findings of the academic researches carried out in tertiary institutions continue to be recycled within the institution as those who ought to apply these reports hardly buy them. Thus, the indispensability of research in national development is being called to question particularly in the developing economies of the world. Bogoro (2014) opined that despite the huge investment in research and development especially in universities, the return-on-investment which can only be justified through researches targeted at problem solving and implemented to actually solve the identified problem is greatly lacking. This informed the NUC's organization of first Nigerian Universities Research and Development Fair in November, 2004.

Bako (2005) opined that research and development has become the most enduring and effective means of boosting sustainable economic development and reinforcing competitiveness in face of rapid growth taking place between industries, countries and peoples in the world. There is ample evidence to show that research and development generated by higher education, more than anything else, has contributed to the rise and expansion of the world knowledge economy, and the establishment, once again, of imperial knowledge hegemony of a few countries over the rest of the world in the on-going process of globalization and its uneven development. This particular point explains why the main criteria for ranking the "world class universities" is not so much the volume of teaching, student population or community services a university could muster, but research output measured by the breakthrough findings published in first class and medal winning journals and books, which could increase the volume and rate of knowledge accumulation. This is why developed countries now refer to their thriving economies as 'knowledge-economy' driven by evidence-based, original and problem-targeted researches. The level of investment by governments in innovative research and development and education determine the global competitiveness of their nations. However, it should be noted that generally the contribution of researchers from Nigerian Universities to global publication and production of knowledge has declined very tremendously (Bako, 2005).

There is no doubt that Science and Technology has been, and will remain the most critical inputs to development processes, particularly in the face of increasingly globalized, knowledge-driven economies. Therefore, deliberate investment in research and development (R&D) is key to the generation of knowledge. However, in Nigeria, and until recently, R&D has been largely a government affair, with very little private sector participation. The transformation agenda recently introduced in Nigeria has witnessed a gradual shift of the national economy from a largely public-sector led and administratively controlled economy to a private-sector led and market-oriented economy. The emergence of Tertiary Education Trust Fund (TETFUND) in Nigeria is a response to the voice of the academic community led by the Academic Staff Union of Universities (ASUU) for increased private sector participation in the development process of Nigeria (Bogoro, 2014).

2.1.2 Problems of research in Nigeria

Nigerian universities are charged with the creation of knowledge and it is one of their primary mandates. In creating knowledge, a lot of researches has to be undertaken by both the universities and research centers. The number of universities has grown astronomically in Nigeria especially with the emergence of state and private universities in addition to Federal universities. Nigeria now has a total of 195 universities comprising 44 federal, 52 state and 99 private universities (NUC, 2021). The increased number of universities has not translated into increased generation or creation of knowledge. This is as a result of numerous challenges facing research activities in Nigeria. Some of these problems are listed below:

i. lack or inadequate funding of research and development by the government

ii. lack of stable Internet connectivity

iii. libraries equipped with outdated materials

iv. poor or inadequate subscription to electronic resources and databases

v. poor research methodology which hinders relevant research findings.

vi. Unreliable power supply.

Imhonopi and Urim (2014) carried out a study to examine factors affecting scholarly research output in Nigeria with focus on the perception of academics in South-western universities. The study revealed positive factors that affected research output among respondents included desire for promotion (64.3%), contribution to knowledge (75.6%) and access to local/international research grants (51.7%). While negative factors that dissuaded respondents were fear of rejection of articles for publications (56.7%), lack of funds (72.6%) and unfavourable university policies/guidelines on promotion (53.7%). This shows that researchers are willing to conduct researches that contribute to knowledge, however lack of funds is a big hindrance. There is the need to increase access to local/international grants to reduce reliance on available limited fund in the university. A well-funded research with proper data management procedures have a higher chance of getting accepted in high impact factor journals internationally.

2.1.3 The scientific research process

Scientific research, according to Blakstad (2008) is performing a methodical study in order to prove a hypothesis or answer a specific question. Finding a definitive answer is the central goal of any experimental process. Research must be systematic and follow a series of steps and a rigid standard protocol. These rules are broadly similar but may vary slightly between the different fields of science.

Scientific research must be organized and undergo planning, including performing literature reviews of past research and evaluating what questions need to be answered. Any type of research, whether scientific, economic or historical, requires some kinds of interpretation and an opinion from the researcher. This opinion is the underlying principle or question that establishes the nature and type of experiment.

Experimental research is commonly used in sciences such as sociology and psychology, physics, chemistry, biology and medicine. It is a collection of research designs which use manipulation and controlled testing to understand causal processes. Generally, one or more variables are manipulated to determine their effect on a dependent variable. The experimental method is a systematic and scientific approach to research in which the researcher manipulates one or more variables, and controls and measures any change in other variables (Blakstad, 2008).

2.1.4 Steps of scientific research process

Science Buddies (2016) gave the following steps in a scientific research process:

i. **Ask a Question**: The scientific method starts when there is the need to ask a question about something observed. The question could be in the form of: How, What, When, Who, Which, Why, or Where?

ii. **Do Background Research**: Rather than starting from scratch in putting together a plan for answering the question, the researcher might start with using the library and Internet search to help find the best way to do things and ensure that mistakes from the past are not repeated.

iii. **Construct a Hypothesis**: A hypothesis is an educated guess about how things work. It is an attempt to answer research question with an explanation that can be tested. A good hypothesis allows researcher to make a prediction. It is necessary to state both hypothesis and the resulting prediction that will be tested. Predictions must be easy to measure.

iv. **Test Hypothesis by Doing an Experiment**: Experiment tests whether prediction is accurate and thus, hypothesis is supported or not. It is important for the experiment to be a fair test; this is achieved by conducting a fair test and making sure that only one factor at a time is changed while keeping all other conditions the same. Experiments should also be repeated several times to make sure that the first results were not just an accident.

v. **Analyse Data and Draw a Conclusion**: Once the experiment is completed, collect the measurements and analyse them to see if they support formulated hypothesis or not. Scientists often find that their predictions were not accurate and their hypothesis was not supported, and in such cases they will communicate the results of their experiment and then go back and construct a new hypothesis and prediction based on the information they learned during their experiment. This starts much of the process of the scientific method over again. Even if they find that their hypothesis was supported, they may want to test it again in a new way.

vi. **Communicate Your Results**: Scientists do this by publishing their final report in a scientific journal or by presenting their results on a poster or during a talk at a scientific meeting or conference. With the advent of ICT and electronic publishing, scientists may also publish their findings on the Internet through various online platforms and social networks.

The diagram below shows the generic steps in scientific research process. Even though the scientific method is depicted as a series of steps, new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an iterative process. These steps are therefore not necessarily linear or rigid.

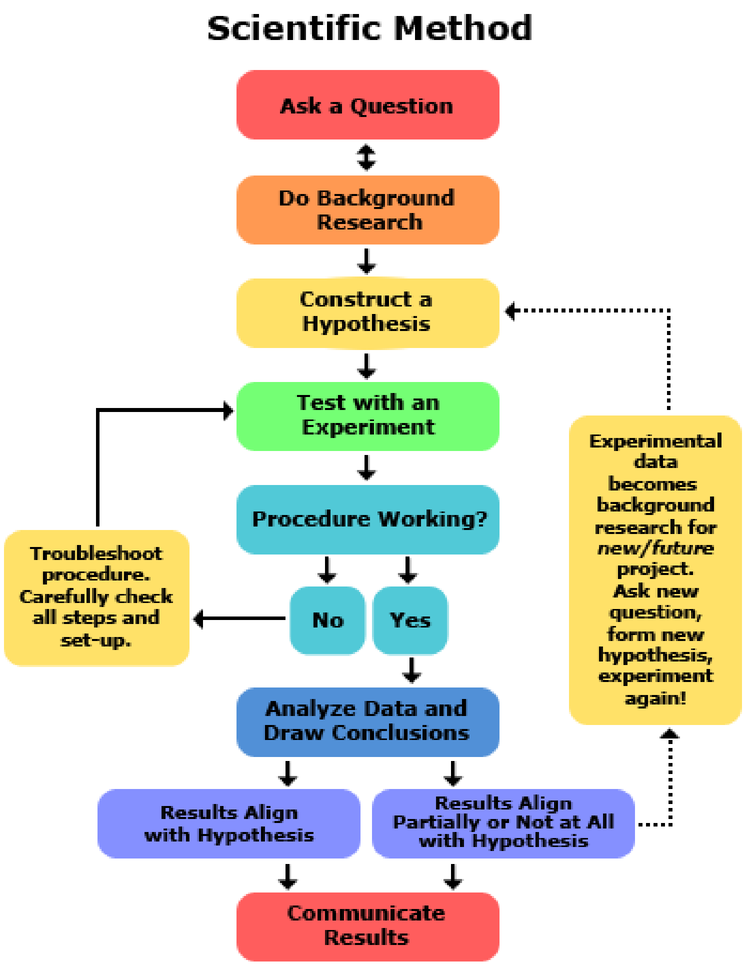


Figure 2.1 Steps of Scientific Research Process
Source: Science Buddies (2016)

2.1.5 Conducting experiments in chemistry

After constructing hypothesis, testing with an experiment in a laboratory occurs. However, the following points must be noted before commencing the experiment:

i. know what to do. Read and understand the experimental procedure. Are all of the necessary steps written down? Are there any questions about how to do any of the steps?

ii. get a laboratory notebook for taking notes and collecting data (see Sample Data Table in Figure 2.2).

iii. be prepared. Collect and organize all materials, supplies and equipment needed to do the experiment. Are all the materials needed available? Are they handy and within reach of the workspace?

iv. think ahead about safety. Are there any safety precautions to take? Is expert supervision needed?

v. data Table. Prepare a data table in laboratory notebook to help collect the data. A data table will ensure that there is consistency in recording data and it will

Trial	Faucet Opening (the Independent Variable)	Water Flow (the Dependent Variable)
#1	1/4 open	[Write your data in this column as you make measurements during your experiment.]
#2	1/4 open	
#3	1/4 open	
#4	1/2 open	
#5	1/2 open	
#6	1/2 open	
#7	3/4 open	
#8	3/4 open	
#9	3/4 open	
#10	Fully open	

make it easier to analyse results once the experiment has been concluded.

Figure 2.2: Sample Experimental Data Table

Source: Science Buddies (2016)

2.1.6 The laboratory notebook

Throughout the process of conducting an experiment, there is usually a journal containing all important ideas and information. This journal is called a laboratory (lab) notebook. A lab notebook is an important part of any research. It contains a detailed and permanent account of every step of the project, from the initial brainstorming to the final data analysis and research report. Many science projects require a number of steps and multiple trials. By recording the steps of the procedure, observations, and any questions that arise, researcher creates a record of the project that documents exactly what is done, when it is done, and why it is done. With a complete record of the project in a lab notebook, the notes can be consulted later if a question arises or if there is a need to pursue a related project based on something observed.

Lab notebook is what some researchers use in keeping their research data, because it is in hardcopy, it becomes challenging to effectively manage the book and its content. Lack of effective research data management results in loss of data and information that would have been used for future researches. This identified gap is what this study hopes to bridge by developing a computer-based data management model that would prevent data loss and promote future reuse of data.

The picture in Figure 2.3 shows sample of laboratory notebooks:

Figure 2.3 Laboratory Notebooks
Source: Science Buddies (2016)

2.1.7 Research data

Research data is as diverse as the disciplines that use it, but can be defined, broadly speaking, as the evidence used to inform or support research conclusions (VanTuyl, 2014; Wallis*et al*., 2013). Also, research data is all data created by researchers in the course of their work, and for which the institution has a curatorial responsibility for at least as long as the code and relevant archives/record keeping acts require. However, there are some data that are worth keeping but are not referred as research data. Examples of such data are:

- administrative data: administrative data consists of records of payrolls, student enrolments, research assessment, and so on. Some administrative data relates to research projects and may need to be treated as research data. However, for the most part it is treated independently within the institution in terms of data management policies, procedures and strategies;
- teaching data: teaching data comprises courseware and other resources which are part of the teaching function of a university. Again, this may be of interest to a research project, but it is usually managed independently;
- research publications: research publications can be regarded as data, but for the most part these are well taken care of outside the institution, by publishers and the like. Even when held within the institution usually in a repository, either on open access or for research reporting purposes, these tend to be managed separately from other research data;

Research data can be classified into digital and non-digital research data. The following are the types of research data: laboratory notebooks; field notebooks; primary research data (including research data in hardcopy or in computer readable form); questionnaires; audiotapes; videotapes; models; photographs; films; test responses. Research collections may include slides; artefacts; specimens; samples. Provenance information about the data might also be included: the how, when, where it was collected and with what (for example, instrument). The software code used to generate, annotate or analyse the data may also be included.

Non-digital research data are recorded data in non-digital formats such as laboratory notebooks, audio/visual data on magnetic tape, optical photographic film, slides and prints and hand-written questionnaires. Often these materials are best digitized as it allows them to be managed and protected as easily as other digital data. If they cannot be digitized, they should be kept securely in a suitable location, such as a fireproof safe.

2.1.8 Importance of research data

Prost *et al*. (2015) provided empirical evidence on research data submitted together with PhD dissertation in Social Sciences and Humanities from the University of Lille 3 in France. The study revealed that submitting research data along with the dissertations can help give 'life' to the documents in future. The question of research data produced along with PhD dissertation has not attracted much attention so far. What obtains in most African countries is attaching a copy of research instrument used for data collection and the final analysis of the instrument. Research data goes beyond these. It entails all kinds and types of data generated in the course of carrying out the research both digital and non-digital.

What is closely related to research data that is usually submitted as an appendix to thesis and dissertations are research findings and results. However, complex digital objects like software, multimedia files, digital art, and other materials, (depending on the discipline) that are sometimes integral to the thesis or dissertation itself are often not attached or preserved. When this material is submitted as a kind of data appendix, the dissertation becomes "gateway" to the data. As a result, a secondary user who finds the dissertation relevant to an area of interest will want to have access to the stored data as well.

For this data to be easily accessed and reused, it has to be properly indexed, well described in a way that is related to the text and connected to other related files. The description of submitted research data (also known as dataset) is the role of an academic librarian.

2.1.9 Describing datasets using metadata

Librarians in academic institutions are expected to have the knowledge of describing digital objects (datasets) using acceptable descriptive standards. Metadata is the description of data in a way that it is uniquely identified and not lost among similar data objects. Metadata is simply information about data. It is a set of descriptive data that gives details about a particular data object. It summarizes basic information about data, making it easier to work with.

Metadata schemes are sets of metadata elements designed for a specific purpose, such as describing a particular type of information resource. There are different types of metadata schema depending on the type of resource to be described. There is Dublin Core Metadata Scheme, Metadata Encoding and Transmission Standard (METS), the Text Encoding Initiative (TEI) and the DataCite Metadata Schema for citing datasets. Appropriate metadata description ensures discoverability and long term preservation of research data. Description and preservation of digital objects are part of the work of academic libraries. Since a copy of completed dissertations or thesis is required to be deposited at the library where it is being managed and preserved, dataset should also be accorded the same reverence. The only difference is that dataset are usually digital object that are best managed electronically on an Institutional Repository (IR).

The evolution of an IR in African University is an advantage to RDM. Institutional Repositories are gradually taking over as some academic libraries today, through the use of Internet, showcase their intellectual contents via Institutional Repositories (Umar *et al*, 2014). In Nigeria for instance, according to the online Directory of Open Access Repositories (2017), a total number of fourteen (14) institutional repositories (www.opendoar.in) are indexed on the OpenDOAR. Most of these repositories are managed by librarians in conjunction with Information and Communication Technology (ICT) units of the universities.

ICT units are responsible for the configuration of the technical aspects of the repositories as well as storage allocation and security. The metadata description and access lies with librarians using their highly relevant skill sets in ensuring that the repository and its contents are discoverable and accessible on the Internet. This will ultimately project the image of the university by improving its presence on the World Wide Web. The direct consequence is increased visibility for the author and Institution of Affiliation, and increased citations and impact factor for both research results and the dataset.

2.1.10 Acknowledging data sources

Secondary users of research data are expected to acknowledge the source of data in a similar way to consulted articles. This is called Data Citation. Data citation is acknowledging the original dataset that is found usable and has been used to further advance the frontier of knowledge. There are services developed to help give appropriate credit to data owners by citing them using standard citation elements. An example is DataCite service that helps to locate, identify, and cite research data using support tools and methods that make data more accessible and useful. DataCite is a leading global non-profit organization that provides persistent identifiers (DOIs) for research data. DOI is an acronym for Digital Object Identifier. DOI is an alphanumeric string assigned to uniquely identify an object. It is tied to a metadata description of the object as well as to a digital location, such as a URL, where all the details about the object are accessible. They support the creation and allocation of identifiers and accompanying metadata. Assigning persistent identifiers to datasets ensure that data becomes citable and offer legitimate contributions to scholarly communication, paving the way for new metrics and publication models that recognize and reward open data and sharing (datacite.org). DataCite also supports journal publishers by enabling research articles to be linked to underlying data or objects and support funding agencies by helping them understand the reach and impact of their funding. Below are the mandatory (M) fields or properties of the DataCite Metadata Schema:

Table 2.1: *DataCite* Metadata Schema showing Mandatory Fields

ID	*Property*	*Obligation*
1	Identifier (with mandatory type sub-property)	M
2	Creator (with optional name identifier and affiliation sub-properties)	M
3	Title (with optional type sub-properties)	M
4	Publisher	M
5	PublicationYear	M
10	ResourceType (with mandatory general type description sub-property)	M

Source: Datacite (2016)

Some of the recommended and/or optional properties are:

Table 2.2: *DataCite* Metadata Schema showing Recommended and Optional Fields

ID	Property	Obligation
6	Subject (with scheme sub-property)	R
7	Contributor (with type, name identifier, and affiliation sub-properties)	R
8	Date (with type sub-property)	R
9	Language	O
11	AlternateIdentifier (with type sub-property)	O
12	RelatedIdentifier (with type and relation type sub-properties)	R
13	Size	O
14	Format	O
15	Version	O
16	Rights	O

An example of data citation using APA citation style:

Milberger, S. (2002). *Evaluation of violence against women with physical disabilities in Michigan, 2000-2001* (ICPSR version) [data file and codebook]. doi:10.3886/ICPSR03414

Another example using mandatory and optional properties:

Milberger, S. (2002). *Evaluation of violence against women with physical disabilities in Michigan, 2000-2001* (ICPSR version) [data file and codebook]. Detroit: Wayne State University [producer]. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor]. doi:10.3886/ICPSR03414

2.1.11 Research data lifecycle models

The importance of lifecycle models is that they provide a structure for considering the many operations that need to be performed on a data record throughout its life. Many curatorial actions can be made considerably easier if they have been prepared for in advance – even at or before the point of record creation. For example, a repository can be more certain of the preservation actions it can perform if the rights and licensing status of the data has already been clarified, and researchers are more likely to be able to detail the methodologies and workflows they used if they record them at the time.

Ball (2012), in his review of Data Management Lifecycle Models, gave the following:

i. DCC curation lifecycle model

The Digital Curation Centre (DCC) has produced a model for aligning curation tasks with the lifecycle stages of a digital object, intended as a planning tool for data creators, curators and users. At the centre of the model are the digital data, which are here identified with simple and complex digital objects or databases.

Description and (management of) representation information: The creation, collection, preservation and maintenance of sufficient metadata to enable the data to be used and reused for as long as they have value to justify continued curation.

Preservation planning: Strategies, policies and procedures for all curation actions.

Community watch and participation: That is, a predetermined group of stakeholders that help to track changes in the data requirements and participates in the development of standards, tools and software relevant for the data.

The curation lifecycle proper begins with the create or receive stage, where ‘create’ refers to original data generated and recorded by researchers, and ‘receive’ refers to pre-existing data collected from other sources. The curation activities at this stage centred on ensuring that all data is accompanied by sufficient administrative, descriptive, structural and technical metadata; ideally, pre-existing data should have these already, but as different researchers and repositories inevitably work to different standards they should be checked for consistency with local policies. In the next stage, Appraise and Select, researchers or data specialists evaluate and select the data to keep for the long term according to documented guidance, policies or legal requirements. Some data may be sent for Disposal: this may involve transferring the data to another custodian, although it could mean simple or secure destruction. Again, the nature of the disposal should be driven by documented guidance, policies or legal requirements.

The remaining data are sent for Ingest by the normal custodian, be it an archive, repository, data centre or some other service. The Ingest stage immediately leads on to the Preservation Action stage, which involves an array of different activities: quality control, cataloguing, classifying, generating fixity data, registering semantic and structural metadata, and so on. Any data that fails quality control checks are returned to the originator for further appraisal. This should result either in improvements in the quality of the data (e.g. corrections to data transfer procedures, improved metadata, repackaging of data) and reselection, or disposal. Some data may need to be migrated to different format, either to normalize it within the system or to reduce risks arising from hardware or obsolescence. Once the data have completed the Preservation Action stage, they pass into Storage.

This principally refers to the initial committal of the data to storage, but various long-term actions that ensure data remain secure may also be associated with this stage: maintaining the storage hardware, refreshing the media, making backup copies, checking for fixity, and so on.

Once the data have been safely stored, they enter a period of Access, Use and Reuse. Curation actions associated with this stage are focused on keeping the data discoverable and accessible to designated users and re-users. This includes, for example, surfacing descriptive metadata through custom search interfaces or public

APIs and ensuring the preservation metadata held for the data continue to meet the requirements of the designated users and re-users.

Aside from ongoing preservation activities, the story of the archived data considered as an object stops at that point, but several events may cause progression to the Transform stage of the lifecycle. A key piece of software or hardware may approach obsolescence, therefore triggering an action to migrate the data to a new format, or a re-user may request a subset or other derivation of the data. The end result is a new set of data which starts the lifecycle again. Data created for a repository's internal purposes will, by its nature, pass through the early lifecycle stages rapidly, while data supplied to a (re-)user will progress as normal.

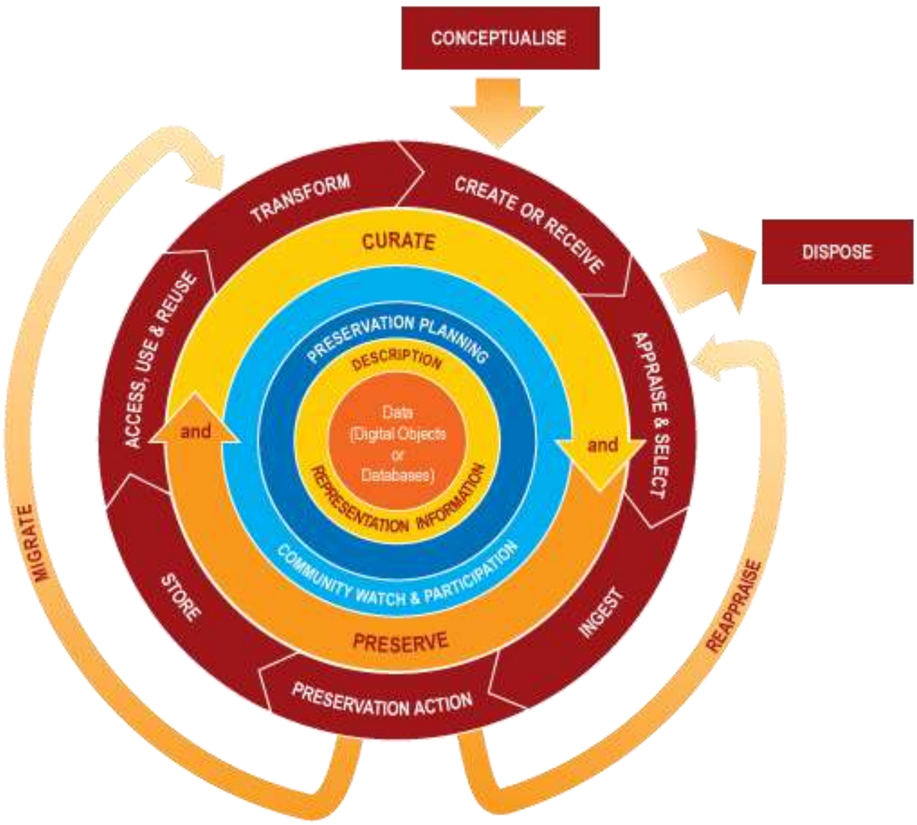


Figure 2.4: DCC Curation Lifecycle Model
Source: dcc.ac.uk

ii. Infrastructure for Integration in Structural Sciences (I2S2) idealized scientific research activity lifecycle model

The I2S2 Project produced a lifecycle model of scientific research from the researcher's point of view. As such it concentrates on the research, publication and administrative activities of the researcher, with only a high-level overview of archiving activity (which, for the most part, will be performed by a specialist). It was used by the I2S2 Project to identify gaps in the provision of tools to help automate, accelerate and integrate the research process. A good place to begin reading the diagram of the model is on the top right-hand corner, with 'Research Concept and/or Experiment Design'. This is the point where researchers are considering a research question and how to answer it; any records from this stage are likely to be produced by hand.

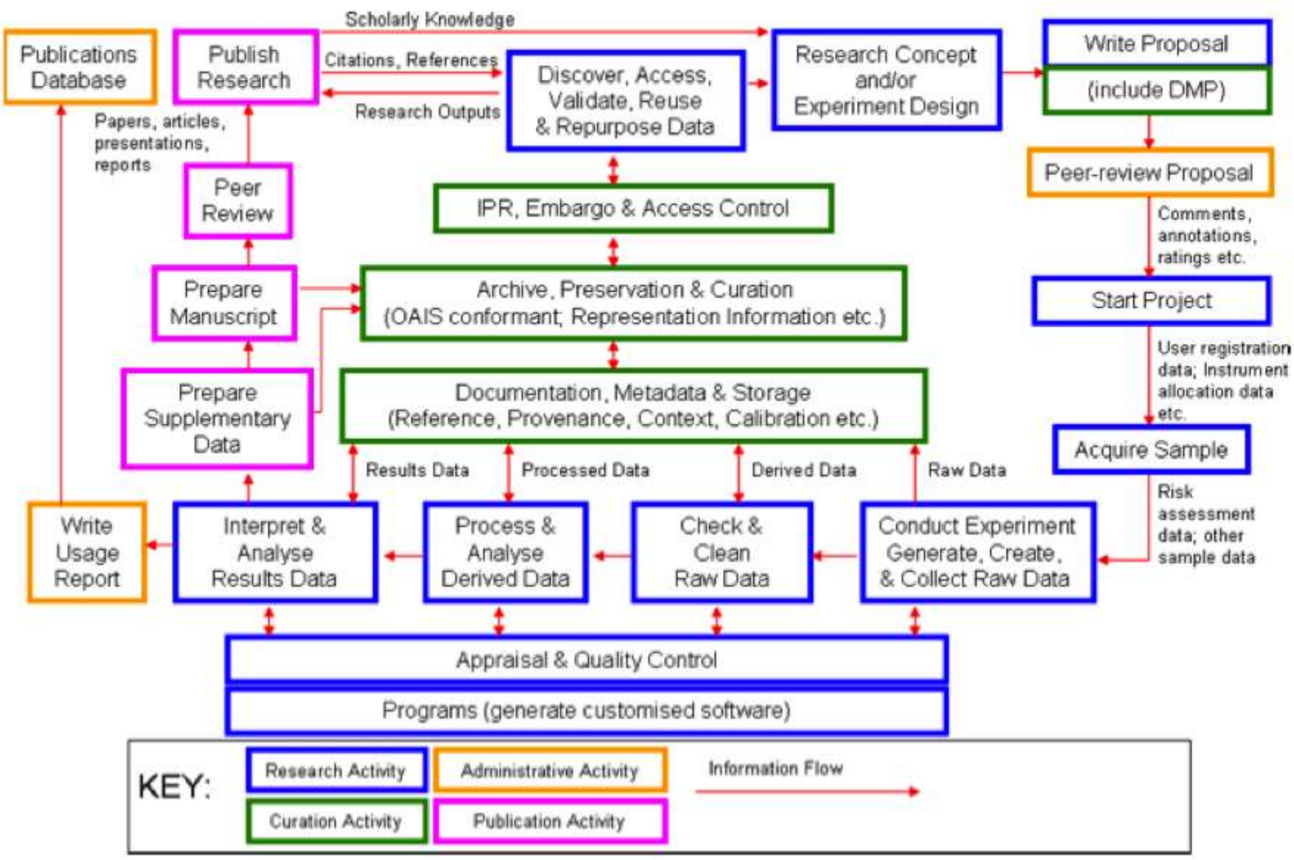
At the next stage, the researchers write a research proposal and a basic data management plan, most likely as electronic documents. These documents are submitted to a funding body, which decides whether or not to fund the proposal based on peer reviews. If the proposal is successful, the project starts. This stage may see the production of fleshed-out project plan, a fuller data management plan, and the documentation of research instruments (whether to hand, acquired specially or, in such cases as questionnaires and interview templates, created by researchers). In some forms of research, additional submissions and approvals may be required before the research can proceed: for example, relating to health and safety or ethics. The next stage involves gaining access to (a sample of) the object of study. Once achieved, the researchers apply the research instruments to the object of study and generate data; they may also generate supplementary information and data providing context for the research. Once the raw data are in hand, the researchers process them in various ways and analyse them (sometimes in an iterative fashion) in order to produce results data. Again, additional information and data about the workflow may be generated along the way. Finally, the researchers interpret the results data in order to answer the original research question. This concludes the research activity, but three other branches of activity continue:

Publication activity: Preparing a public version of the data, writing a journal paper, submitting both for publication;

Administrative activity: writing final project reports for funders, writing internal usage reports, and recording the publication activity;

Archiving activity: most likely performed by a data archive or institutional data repository.

The life cycle completes when a future researcher consults the archived data and uses



them as an inspiration for or input to a further research project

Figure 2.5: I2S2 Idealized Scientific Research Activity Lifecycle Model

Source: Ball (2012)

iii. DDI combined life cycle model

The Data Documentation Initiative (DDI) version 3.0 Conceptual Model contains combined life cycle model for research data, particularly social science data. The name signifies the fact that the model was formed by combining the initial draft of the model, constructed from a data application perspective, with elements from another model. The model is linear for the most part, with one alternative path and one feedback loop; a graphical representation can be found as Figure 2.6. It has the following eight elements:

Study concept: the earliest stage in the model is the point at which a survey is being designed. The model includes not only the choice of research question to answer and the methodology for collecting the requisite data, but also plans for the way in which the data will be processed, analysed and used to answer the question, and the form that answer will take. Researchers should also define at this stage the relationships that will exist between the data products of the research.

Data collection:examples given of collection methods and sources include surveys, censuses, voting or health records, commerce statistics or Web-based collections. Primary and secondary data sources should be clearly distinguished.

Data processing: once the input data has been assembled, it is processed and analysed to produce output data (e.g. a statistic or set thereof) that answers the research question. These output data may be recorded in a machine-readable form or human-orientated form such as a technical report.

Data archiving:in order to ensure long-term access to the data, they should be passed to an archive rather than merely kept by researchers. The archive not only preserves the data (and metadata) but also adds value to them over time.

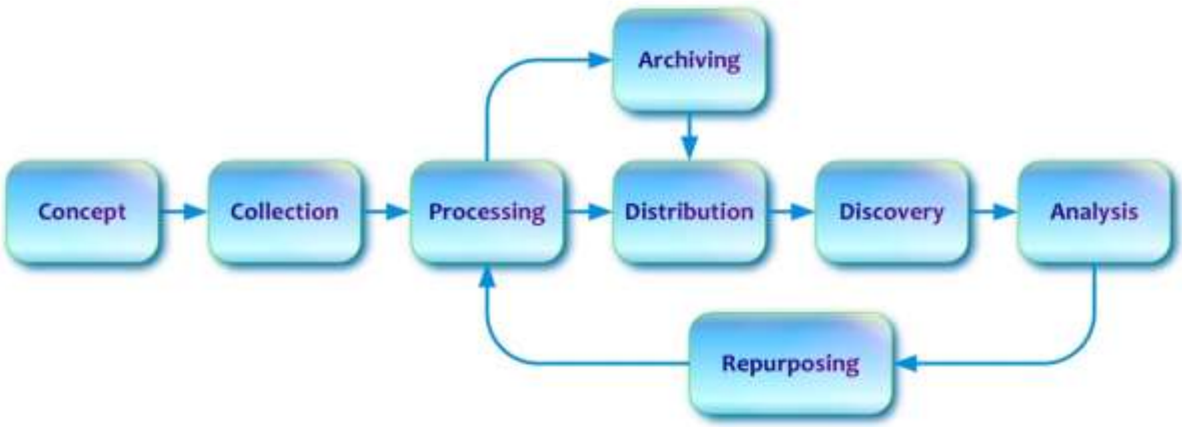
Data distribution: the data are distributed to users either directly or via a library or data archive.

Data discovery:the data may be publicized through books, journal publications, Webpages or other online services.

Data analysis: the data may be used by others within the bounds of the original conceptualization; for example, picking out key statistics for a research report.

Repurposing: the data may also be used within a different conceptual framework; examples include sampling or restructuring the data, combining the data with other similar sets, or producing pedagogic materials.

Within the DDI standard, this model was used to group metadata requirements into five modules: study conception, data collection process, logical structure of encoded



data, physical structure of encoded data, and archiving.

Figure 2.6: DDI Combined Data Lifecycle Model

Source: www.ddialliance.org

vi. DataONE data lifecycle

The Data Observation Network for Earth (DataONE) uses a sequence of verbs, similar to the Australian National Data Service (ANDS) verbs to describe the data lifecycle. It uses this lifecycle to place the tools from its toolkit into context.

Plan: Creating a data management plan to control how data are handled throughout the research project.

Collect: Acquiring data from sensors, laboratory instruments and measurement equipment in the field, and organizing them in spreadsheets or databases.

Assure: Agreeing standard formats, codes, and units for the data and applying quality control procedures such as double entry, database input filters and outlier detection.

Describe: Providing sufficient metadata to ensure the data are independently understandable and reusable.

Preserve: Depositing data in a data centre or repository so they may be protected from bit-level degradation and format obsolescence.

Discover: Exposing discovery metadata through a searchable interface and using such an interface to locate relevant data.

Integrate: Transforming several different datasets into a common representation (format, coding scheme, and ontology), accounting for methodological and semantic differences while preserving a provenance trail.

Analyse: applying statistical and analytical models to the data in order to extract meaningful answers to research questions.

Figure 2.7 DataONE Data Lifecycle
Source: www.dataone.org

vi. UK Data Archive data lifecycle

The UK Data Archive provides a data lifecycle model as an aid to researchers considering how data management relates to the lifecycle of a research project. The model defines the following six stages.

Creating data: design research, plan data management (formats, storage), plan consent for sharing, locate existing data, collect data (experiment, observe, measure, simulate), capture and create metadata.

Processing data: enter data, digitize, transcribe, translate, check, validate, clean data, anonymize data where necessary, describe data, manage and store data.

Analysing data: interpret data, derive data, produce research outputs, author publications, and prepare data for preservation.

Preserving data: migrate data to best format, migrate data to suitable medium, back-up and store data, create metadata and documentation, archive data.

Giving access to data: distribute data, share data, control access, establish copyright, and promote data.

Re-using data: follow-up research, new research, undertakes research reviews, scrutinize findings, teach and learn.

The UK Data Archive Data Lifecycle is diagrammatically represented in Figure 2.8:

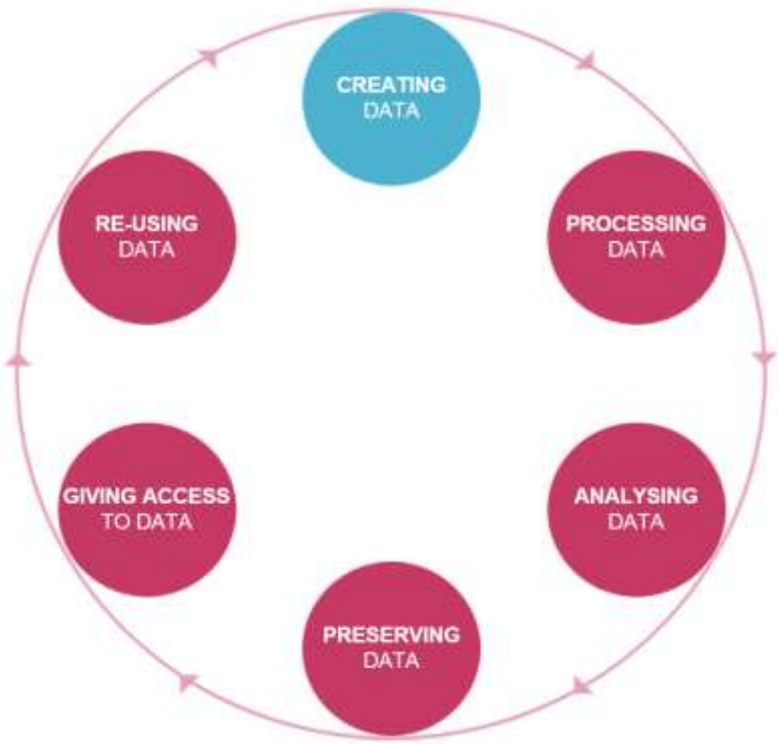


Figure 2.8: UK Data Archive Data Lifecycle
Source: data-archive.ac.uk

vi. Research360 institutional research lifecycle

The Research360 Project has developed a six-stage Institutional Research Lifecycle model. The model can be seen as a high-level summary of the I2S2 model above simplified to resemble the UKDA Lifecycle model (also above). The main differences between the UKDA model and that of Research360 are that the latter has an additional planning stage at the start and no processing stage.

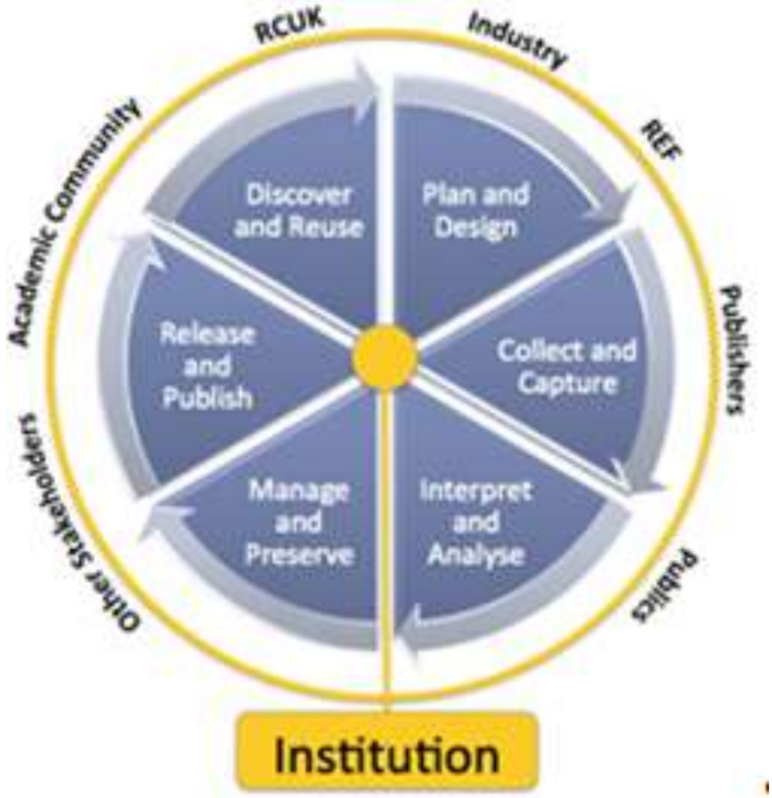


Figure 2.9: Research360 Institutional Research Lifecycle
Source: www2.le.ac.uk

A tabular overview of the data lifecycle models reviewed so far is attached on Appendix L.

From the foregoing, all the data lifecycle models reviewed so far represents the various stages of transformation of research data right from its conception, birth, rebirth and its final demise. This study deduced that these lifecycles are typical of a standard research environment that has all necessary management support with effective intrinsic and extrinsic motivation. However, the Nigerian research environment, as discovered during preliminary investigation of this study, suffers numerous problems that adversely affect the way researchers conduct their research. It therefore becomes pertinent to understand the research workplace with specific reference to chemistry research and develop a data management model that will suit the identified researchers' workflow in Nigeria.

2.1.12 Research data management

Research data management is the process involved in managing research data and the services and policies that support these activities. It refers to activities and practices that support long-term preservation, access and use of data. Specifically, data management activities include:

i. Planning of data
ii. Documenting of data
iii. Formatting
iv. Storing
v. Anonymizing and
vi. Controlling access

Data management helps researchers to do better research. It helps to optimize use of data during the active phase of the research project and collaborate with other researchers. Data management also ensures that data is preserved for future researchers to discover, interpret, and reuse. Furthermore, it sustains the value of data and support new research or extends previous researches. Research data management occurs at every stage of data lifecycle.

2.1.13 Data management across the research lifecycle

A data management plan (DMP) is a formal document that describes how a researcher would manage research data during the research and after the research is completed, that is across the research data lifecycle. It describes the data that will be created, the standards used to describe the data (metadata), who owns the data, who can access the data, how long the data will be preserved (and/or made accessible), and what facilities and equipment will be necessary to disseminate, share, and/or preserve the data. According to the Research Data Management and Sharing Moodle on the Coursera platform organized by the University of North Carolina, Chapel Hill and the University of Edinburg, as taught by Tibbo & Jones (2016), the following are questions to be answered in preparing a data management plan:

i. What data will be collected? This includes the type, format, volume, storage implications.

ii. How will the data be collected or created? This includes data collection methods, file organization and version control, quality assurance protocols.

iii. What documentation and metadata will accompany the data? This includes data format that is easily understandable to secondary users (for reuse) and for original user in the future. Documentation needed for interpretation and use e.g. description of methodology, codebooks, questionnaire instruments, analysis procedures.

iv. How will ethical issues be managed? This includes issues related to law and guidance regarding protection of human subjects, provisions for protecting confidentiality, strategies for handling and storing sensitive data, restricting access to data, preparing de-identified datasets for sharing.

v. How will copyright and intellectual property rights issues be managed? This includes issues of data ownership and conditions for use.

vi. How will data be stored and backed up during research? This includes provisions for storage, plans for systematic backup of data files.

vii. How will access to and security of data files be managed? For instance, sensitive data and other security measures should be available to ensure that only authorized personnel are granted access. Also, description of compliance with standards should be incorporated.

viii. Which data should be retained, shared and or preserved? That is, determine the potential value of data.

ix. What is the long-term preservation plan for datasets? Identify a repository to archive the data, plans to prepare and document the data to ensure preservation and use.

x. How will data be shared? Identify mechanism for sharing data, describe how others might find the data, how data will be delivered, also specify how you would like to be acknowledged or cited.

xi. Are there any restrictions on data sharing required? Identify privacy concerns and how to overcome concerns either by anonymizing data, data use agreement or other mechanisms. Also explain embargo on data and when it will be lifted.

xii. Who will be responsible for data management? Name (if possible) the person responsible for overseeing the implementation of the Data Management Plan (DMP).

xiii. What resources will be required to implement the DMP? This is necessary for complex data that requires specialized expertise or equipment, cost of ongoing data management tasks, resources required for long-term preservation of data in the repository.

2.1.14 Data management stakeholders

Pinefield*et al.*(2014) gave the following as stakeholders involved in any successful data management process:

i. Primary researchers (faculty staff, graduate students, research assistants)

- design the study
- specify what data will be collected

- determine how to analyse data
- draw conclusions from these analyses

ii. Institutions (Universities and Research Institutes)

- set internal data management policies
- provide data management resources like data management training kit, data management plans support.

iii. Library (Librarians)

- curate data
- ensure the long-term preservation of data
- provide access to data
- gives training and advisory support to researchers on data management
- work with institutional repositories to ensure data is useful over time.
- In conjunction with primary researchers, they determine and decide access restrictions to data including those ordered by the institutions, funding agencies as well as copyright and intellectual property concerns.

iv. Research Office

- Inform researchers on latest requirements of funding agencies
- Provide information on data management plans
- Guide researchers on grant proposal writing and research best practises.

v. Information Technology Service (ITS) Unit

- responsible for storage space allocation

- ensuring security of the repository
- offer technical IT support

The varieties of stakeholders suggest the need for proper data management throughout the research lifecycle. This requires communication and corporation between these various groups.

The study focused on all stakeholders to ensure an effective implementation of RDM in federal universities of technology in Nigeria.

2.1.15 Role of libraries in research data management

Academic librarians can offer relevant leadership in RDM efforts within their universities. Although collaboration across the institution is key in developing an RDM program, libraries play an essential coordination role in the process. Stakeholder groups such as university administrators, researchers, and research support units all have an interest in how RDM services are designed for their institution. The library is uniquely positioned to support RDM services because they have the staff (librarians) with the expertise and a campus-wide relationship with the other stakeholders.

Flores *et al* (2015) opined that "the library is well situated to be a key player in data management, curation, and preservation, given its extensive experience with selection, metadata, collections, institutional repositories, preservation, curation and access". Academic libraries have a history of provisioning data for research use, giving many librarians a familiarity with the reuse requirements and concerns surrounding research data.

Academic libraries find more and more opportunities to provide services throughout the different phases of the research life cycle hence; RDM is one of these areas. RDM offers an opportunity for libraries to reformulate their role in the life of the university.

Libraries offering RDM services can have a great impact on their campus communities by supporting communication among researchers, enhancing knowledge of the data life cycle, providing disciplinary and institutional resources, and emphasizing the importance of documentation and data sharing (McLure *et al*., 2014).

2.1.16 Developing a data management model for chemistry research in Nigeria

From the reviewed literature so far, there is no existing data management model that can be applied to the Nigerian research environment, specifically for chemistry research. In developing a prototype data management model for chemistry research in Nigeria, this study adopted the evolutionary prototyping to guide the development process.

2.1.17 Evolutionary prototype

The evolutionary prototype is a systems development method (SDM) in which a prototype (an early approximation of a final system or product) is built, tested, and then reworked when necessary until an acceptable prototype is finally achieved from which the complete system or product can now be developed. This model works best in scenarios where not all the project requirements are known in detail ahead of time. It is an iterative, trial-and-error process that takes place between the developers and the users (teach-ict.com, 2020).

The following are steps in the evolutionary prototype:

1. the new system requirements are defined in as much detail as possible. This usually involves interviewing a number of users representing all the departments or aspects of the existing system;
2. a preliminary design is created for the new system;

3. a first prototype of the new system is constructed from the preliminary design. This is usually a scaled-down system, and represents an approximation of the characteristics of the final product;
4. the users thoroughly evaluate the first prototype, noting its strengths and weaknesses, what needs to be added, and what should be removed. The developer collects and analyses the remarks from the users;
5. the first prototype is modified, based on the comments supplied by the users, and a second prototype of the new system is constructed;
6. the second prototype is evaluated in the same manner as the first prototype;
7. the preceding steps are iterated as many times as necessary, until the users are satisfied that the prototype represents the final product desired;
8. The final system is constructed based on the final prototype;
9. Routine maintenance is carried out on a continuing basis to prevent large-scale failures and to minimize downtime.

This study adopted this model because first, there is the need to understand the existing workflow of chemists. Second, an initial prototype was presented to the users for feedback and suggestions for improvement. The suggestions were incorporated and new prototype re-presented to users until they were satisfied. Then, a technology acceptance testing using the Unified Theory of Acceptance and Use of Technology (UTAUT) was conducted to determine whether the prototype will be used or not. So at each stage, the prototype evolves towards the final system, hence the term 'evolutionary prototyping'. This is relevant to the study because the data management model seeks to, as much as possible, be usable and adoptable by chemists in Nigeria.

Figure 2.10 shows the diagrammatic representation of an evolutionary prototyping:

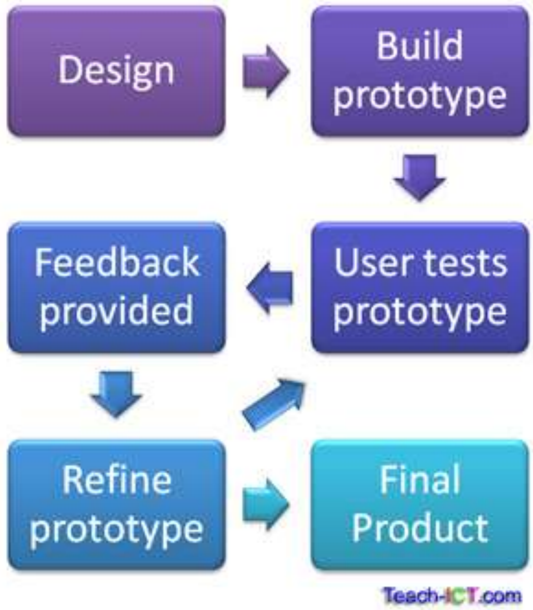


Figure 2.10 Evolutionary Prototype Model
Source: Prototyping (2020)

2.2 Theoretical Framework

2.2.1 Technology acceptance models

Technology is anything that helps do our work better and easier with less time spent. Acceptance can be viewed as a function of user's involvement in technology use (Samaradiwakara & Gunawardena, 2014). User's acceptance of technology is therefore seen as a demonstrable willingness within a user's group to employ information technology (IT) for the tasks it is designed to support (Dillon, 2001).A technology that is not accepted for use is of little value. There are many theories of technology acceptance and use model all geared towards understanding factors that affect usage of a particular technology (Park 2009; Alharbi & Drew 2014; Williams*et al.*,2014).

The technology studied varies from users' behavioural intention to use e-learning systems, learning management system, online zakat system, adoption of internet banking,to customer acceptance of radio frequency (Chen *et al.*, 2011).

Advancement in researches has seen many researchers and several studies adding variables to the Davis (1989) technology advancement model (Chen *et al.*, 2011). This has given rise to other models like Technology Acceptance Model 2 (TAM 2), Technology Acceptance Model 3 (TAM3), integrated model of TAM and Theory of Planned Behaviour (TPB) also known as Combined TAM-TPB, integration of technology readiness and Technology Acceptance Model (TRAM) and a combined model of Task-Technology Fit and Technology Acceptance Model, amongst others. Table 2.3 shows the overview of constructs from some of these models:

Theory	Constructs	Definition

Table 2.3: Models of Acceptance of Technology

1. Theory of Reasoned Action (TRA)	Attitude Toward Behaviour	The positive or negative feeling that an individual has towards certain behaviour.
	Subjective Norm	An individual experiences others thinking that he should or should not have that kind of behaviour.
2. Technology Acceptance Model (TAM)	Perceived Usefulness	The degree that the user believes that using the information system can improve work performance.
	Perceived Ease of Use	The degree that an individual believes it is easy to use the system
	Subjective Norm	An individual experiences others thinking that he should or should not have that kind of behaviour.
3. Motivational Model (MM)	Extrinsic Motivation	User has the feeling to perform some actions because of some activities, improvement of work, salary and advertisement.
	Intrinsic Motivation	User has the feeling to perform certain behaviours because he wants to, not because of any obvious stimulus.
4. Theory of Planned Behaviour (TPB)	Attitude Toward Behaviour	The positive or negative feeling that an individual has towards certain behaviour.
	Subjective Norm	An individual experiences others thinking that he should or should not have that kind of behaviour.
	Perceived Behavioural Control	The restriction that an individual has experienced from inside and outside towards his behaviour.
5. Combined TAM and TPB (C-TAM-TPB)	Attitude Toward Behaviour	The positive or negative feeling that an individual has towards certain behaviour.
	Subjective Norm	An individual experiences others thinking that he should or should not have that kind of behaviour.
	Perceived Behavioural Control	The restriction that an individual has experienced from inside and outside towards his behaviour.
	Perceived Usefulness	The degree that the user believes that using the information system can improve work performance
6. Model of PC Utilization (MPCU)	Job-fit	The degree that the system can strengthen an individual’s work performance.
	Complexity	The degree that the system is difficult to understand and use.
	Long-term Consequences	The result will be somewhat benefited in the future.

Table 2.3 - Continuation

	Affect Towards Use	An individual feels joyful, happy, depressed and detesting towards certain behaviour.
	Social Factors	The internalization of individual towards team culture and the agreement with the group.
	Facilitating Conditions	The subjective factor that makes people feel it is easy to take action under a certain environment.
7. Innovation Diffusion Theory (IDT)	Relative Advantage	The degree of using new method and it can do better.
	Ease of Use	The degree of using new system and make people feel difficult to use.
	Image	The degree that using new system can strengthen others' impression.
	Visibility	The degree that one can observe different users to use the new system in the organization
	Compatibility	The degree that user feels the new system is in chorus with the value of existence, demand, and experience.
	Results Demonstrability	The substantial result of using new system includes the things that are visible and can be expressed by languages.
	Voluntariness of Use	The user experiences the innovation of the new system and begins to have voluntariness and freedom.
8. Social Cognitive Theory (SCT)	Outcome Expectations-Performance	The performance expectancy is related to the result of behaviour, especially the performance expectancy that is related to work.
	Outcome Expectations-Personal	The individual expectancy is related to the result of behaviour, especially personal respect and achievement feeling.
	Self-efficacy	The judgment ability that an individual has when using a kind of technique to complete a specific work or assignment.
	Affect	Personal interest towards a special behaviour.
	Anxiety	The anxiety or emotional response that an individual has when performance behaviour is involved.

Source: Venkatesh *et al*(2003) as cited in Wu *et al*(2008)

2.2.2 Unified theory of acceptance and use of technology model

Venkatesh *et al.* (2003) as cited in Wu *et al.*(2008) integrated and developed a new model known as the Unified Theory of Acceptance and Use of Technology (UTAUT)model by integrating every major parallel aspect of user acceptance determinants from eight models discussed earlier (see Table 2.3). Before then, several researchers have explored the existing models in a bid to predict behavioural intention to adopt and use Information Technology (IT). Subsequently, Venkatesh*et al* validated the UTAUT model against the eight existing models and eventually discovered that the Unified theory (UTAUT) outperformed all the eight existing models with an impressive 70% (adjusted R square) of the variance in behavioural intention (BI) and about 50% in actual use (Kolog *et al*, 2015). The UTAUT model was further empirically validated by a study conducted by Alblooshi and Abdulhamid(2019).

The unification of the eight models produced the UTAUT four core constructs which are *Performance Expectancy (PE)*, *Effort Expectancy (EE)*, *Social Influence (SE)*, and *Facilitating Conditions (FC)*. There are also four control variables for moderating the four core constructs. The control variables are “Gender”, “Age”, “Experience” and “Voluntariness of use”.

Figure 2.11 shows the diagrammatic representation of the UTAUT model:

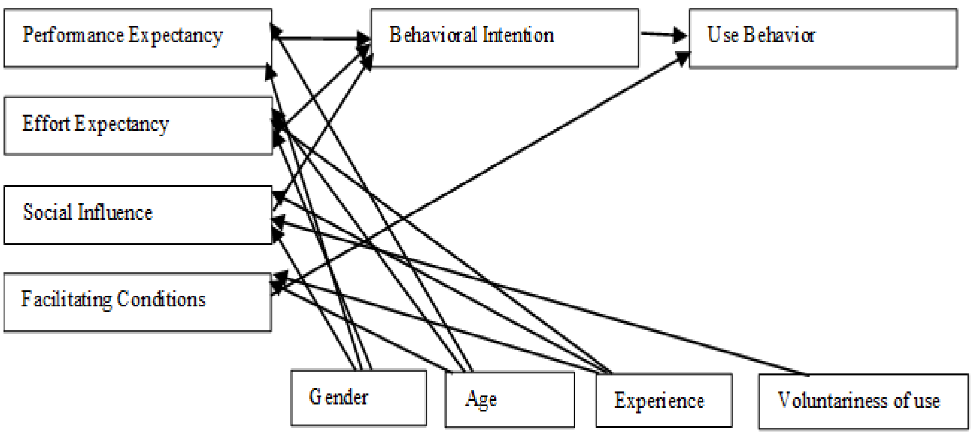


Figure 2.11 Unified Theory of Acceptance and Use of Technology Model (UTAUT)

Source: Venkatesh*et al.*(2003)

The four constructs of UTAUT Model and how it was derived from the integrated model is shown in Table 2.4:

Table 2.4: The four Core Constructs of UTAUT

UTAUT determinant	The sub-determinant	The source of integrated model
Performance Expectancy/PE	Perceived usefulness	TAM/TAM2/ C-TAM-TPB
	Extrinsic motivation	MM
	Job-fit	MPCU
	Relative advantage	IDT
	Outcome expectations	SCT
Effort Expectancy/EE	Perceived ease of use	TAM/TAM2
	Complexity	MPCU
	Ease of use	IDT
Social Influence/SI	Subjective norm	TRA, TAM2, TPB/DPTB, C-TAM/TPB
	Social factors	MPCU
	Image	IDT
Facilitating Conditions/FC	Perceived behavioural control	TPB/DTPB, C-TAM-TPB
	Facilitating conditions	MPCU
	Compatibility	IDT

Source: Venkatesh *et al.* (2003) as cited in Wu *et al.* (2008)

The four core constructs of UTUAT model are explained below:

i. **performance expectancy**: the degree to which an individual believes that using a particular system would improve his or her job performance;

ii. **effort expectancy**: the degree of simplicity associated with the use of a particular system;

iii. **social influence**: the degree to which an individual perceives that others believe he or she should use a particular system;

iv. facilitating conditions: the degree to which an individual believes that an organizational and technical infrastructure exist to support the use of a particular system.

Gender, age, experience and voluntariness of use are moderators which directly or indirectly affect the core constructs depending on their relevance to the technology under study.

2.2.3 Framework for the study – authors' concept

From the foregoing, UTAUT model was adapted for the study. This is because the constructs and the moderating variables are relevant to the technology acceptance testing of the data management model in chemistry research. However, the study will introduce a new moderating variable known as "research experience" and will not use "voluntariness of use". Therefore, 'experience' as postulated by Venkatesh *et al.* (2003) as a moderating variable will be divided into "work experience" and "research experience".

Experience is an important factor in the acceptance of a data management prototype. This is because understanding the data lifecycle requires a certain level of research experience and the aim of this study was to ensure that the prototype reflects the existing research process of chemists in FUTs in Nigeria. Research experience is measured by number of projects supervised, conference attendance and paper presentations, journal publications, book publications and patented items or ideas. Work experience, on the other hand, is simply the number of years spent as an academic staff of the university.

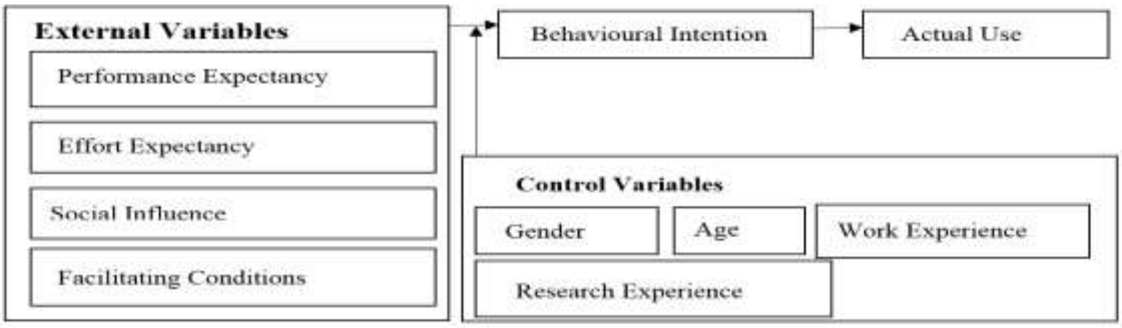


Figure 2.12: The Study Framework

2.3 Empirical studies on data management practices of researchers

The need for effective research data management practice by researchers cannot be overemphasized. This is because loss of research data will make it practically impossible to replicate a study or support the findings in a study. Gonzalez and Peres-Neto (2015) observed that "information is lost when researchers fail to store, archive or share their data, this could be as a result of ageing technology or corruption of data-storage devices. A culture of systematic data curation is needed to stem this loss, but it is not yet in place across research fields".

In an effort to prevent loss of research, universities, research institutes and data archiving centres in developed countries are mounting various ways and methods of assisting researchers in managing their research data for preservation and future reuse. Some of these ways are by offering training on research data management, providing advisory services on data management, development of data management plan toolkits, and funding studies on data management practice of researchers in their universities.

D'Ignazio and Qin (2008) carried out a study, funded by the United States National Science Foundation, on a campus-wide census of Science Technology Engineering and Management (STEM) departments in an institution. The study surveyed the attitude, practices and experiences of researchers with data, and concluded that Library and Information Science (LIS) fields should integrate a Science Data Literacy education involving STEM departments actively working with science data.

Kuula and Borg (2008) presented findings of a funded online survey targeting professors of human sciences, social sciences and behavioural sciences in Finnish universities. The respondents were asked about the state and use of data collected during research in their department/institute. Although respondents considered preservation and use of digital research data to be relevant to their department, there were no guidelines or regulations on the preservation of digital research data. This opinion was supported by 90% of respondents. The survey results also revealed that research data collected remain in the hands of original researchers as supported by 85% of the respondents, and the data was neither archived in the department (75%), archived at a public data archive (74%), nor at the university archive (81%). This shows that after completing research projects, researchers store data by themselves but without any long-term preservation plan. The study however suggested that the easiest solution would be to have a plan for research data preservation carried out at the departmental level.

Sewerin *et al.*(2014) studied research data management faculty practices from a Canadian perspective. In the study, researchers were sampled from the University of Toronto's Faculty of Applied Science and Engineering and postdoctoral fellows. The study was conducted by librarians to determine faculty practice and attitudes toward storing and sharing their research data. To support the need for a study that is discipline-based, faculty in the Health Sciences were not studied due to different data management practices largely shaped by stringent ethics requirement. The study further observed that there is the need for harmonization of funding requirements by funding agencies as regards data management plan in Canada. The study concluded that there is the need for librarians to help researchers on data management so as to save time in other aspects of data management and sharing.

VanTuyl and Michalek (2015) assessed research data management practices of faculty at Carnegie Mellon University. The study conducted a survey using modified instrument from existing similar studies to suit the specific local conditions at Carnegie Mellon University. This buttresses the need for a study targeted at the existing research condition of the university under study. In the study, survey questions included awareness of changes in research data management requirements by funders, amount of data produced and shared, and general data management practices such as the use of data management plans, storage and data practices. In addition to the survey, the study also conducted an in-depth interview to cover a general overview of faculty member's research programme, encompassing all the research they conduct and oversee. This supports the introduction of 'research experience' as a variable adopted in the study framework of this study. Research experience, such as students' project supervisions, journal publications, books, conference papers, patented research findings, determines the use of a data management model. The study concluded that 51% of researchers require support for in-depth data management planning for lifecycle of the project. Also, interview results revealed that the use of available formal data management plans as requested by funding agencies, result in exasperation and frustration as the plans were either not meaningful or they provide a vague framework for data management.

Chiware and Mathe (2015) presented a South African perspective as regards academic libraries' role in research data management services. The study recognized the fact that RDM services are being implemented by academic and research libraries globally in support of university research activities. In South Africa, some libraries are beginning to provide frameworks for these services with some degree of successes as policies are being formulated, infrastructure set up, library staff trained and awareness and advocacy campaigns held with academic staff and researchers. Based on users' requirements, research support tools such as data management plan are being developed and implemented into the institutional research workflow. The study concluded that there is the need for further skills development within the library as they strive to support research data services.

It is worthy of mention that Library and Information Science (LIS) researchers are championing researches aimed at studying scientists to understand their information behaviours in a changing scholarly publishing environment. This helps in contributing information management infrastructure to aid scientists; although this infrastructure would have to be oriented to the variety of local, distinctive, field-based approaches currently existing in the researchers' work environment (D'Ignazio and Qin, 2008).

2.4 Summary of literature reviewed

The following provide summary of reviewed literature, which covers conceptual, theoretical and empirical review.

Research data management, storage, preservation, reuse and sharing is very vital for verifying findings of a research, replicability, transparency, return on investment and for the good of the scientific community.

There are various data lifecycle models developed by international institutions and agencies in developed countries aimed at representing the stages of transformation of research data and associated data management activities as reflected by their research environment.

Data management plans are required to be submitted by funding agencies and publishers as part of grant applications and before manuscripts are accepted for publications respectively. Chemists in federal universities of technology in Nigeria require a data management model that is relevant to their existing workflow and research environment. The data management model should be able to manage their growing experimental data for preservation and future reuse.

A developed model must be tested for technology acceptance to assure its continued use. Hence, there is the need for conducting an acceptance testing of data management model by measuring external variables that could determine Chemists' behavioural intention to use the data management model.

Constructs from the Unified Theory Acceptance of Use of Technology model was analysed and a study framework for this study was developed from it. The external variables, which are the independent variables in this study are "performance expectancy (PE)", "effort expectancy (EE)", "social influence (SI)" and "facilitating conditions (FC)". The outcome variables, which are the dependent variables in this study is the "behavioural intention" to "actual use" the data management model. Moderating variables include 'gender', 'age', 'work experience', and 'research experience'. Empirical review of existing studies on data management practice was observed in order to identify gaps in the studies.

2.5 Gaps in knowledge

From the literature reviewed thus far, the following were identified gaps in knowledge:

i. there is the need for librarians to help researchers in proper data management so as to save time in other aspects of their research;

ii. there is the need for assisting researchers by developing new services such as assistance in depositing research data in an appropriate repository, and guidance on writing a data management plan;

iii. there is the need for a domain-specific computer-based data management model that will assist researchers in conducting evidence-driven researches through effective data management and sharing.

This study took cognizance of these gaps and developed a computer-based data management model for chemistry research in federal universities of technology in Nigeria. Technology acceptance testing was also conducted on the developed system. Further studies may however, replicate this study in other fields of Science, Technology, Engineering and Management (STEM) in Nigeria.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

The exploratory research design using mixed method approach was used for the study. The sequential exploratory strategy involves a first phase of qualitative data collection and analysis, followed by a second phase of quantitative data and analysis that builds on the results of the first qualitative phase. Using a three-phase approach, the researcher first gathered qualitative data and analysed it (Phase 1); use the analyses to develop a model (Phase 2) that was subsequently testedby the targeted population (Phase 3). This model is especially advantageous when a researcher is building a new model (Creswell, 2009).

3.2 Population of the Study

The population of the study comprises the entire chemists from the Department of Chemistry with a PhD or currently undergoing doctoral programme across the available options in chemistry,university librarians,directors of research offices, and directors of Information Technology Units of federal universities of technology in Nigeria. These federal universities of technology are Federal University of Technology, Minna, Federal University of Technology, Akure, Federal University of Technology, Owerri, Modibbo Adama University of Technology Yola, and Abubakar Tafawa Balewa University, Bauchi.

Table 3.1 gives an overview of the population of each of the FUTs:

Table 3.1: Population of Study

S/N	University	Population
1.	Abubakar Tafawa Balewa University, Bauchi, (ATBU), Bauchi State	11
2.	Federal University of Technology, Akure, (FUTA), Ondo State	26
3.	Federal University of Technology Minna, (FUTMIN), Niger State	15
4.	Federal University of Technology, Owerri, (FUTO), Imo State	22
5.	Modibbo Adama University of Technology, Yola, (MAUTECH), Adamawa State	11
	Total Number of Chemists	**85**
	Supporting Stakeholders across FUTs in Nigeria	
1.	University Librarians	5
2.	Directors of ITS Units	5
3.	Directors of Research and Development Units	5
	Total Number of Supporting Stakeholders	**15**

Grand Total	100

3.3 Sample and Sampling Technique

Total enumeration technique was used to cover all chemists with a PhD or currently undergoing doctoral training in the Department of Chemistry in all federal universities of technology in Nigeria. Then, stratified sampling method was used to divide the population into different subgroups (strata) and to select subjects from each stratum in a proportionate manner (Dudovskiy, 2018). Chemistry as a field of study has various options or areas that researchers can specialise on. The options include: Industrial Chemistry, Organic Chemistry, Inorganic Chemistry, Environmental Chemistry, Analytical Chemistry, Physical Chemistry, Polymer Chemistry, and Nano Chemistry. The rank of chemists also vary from Professor, Associate Professor, Senior Lecturer, Lecturer I, Lecturer II and Assistant Lecturer. The prototype data management model must note the specific data management practices of each option and rank and capture their needs adequately.

The rank stratum was also divided into two (2) groups: Group 1 comprisedProfessor and Associate Professor; while Group 2 was for Senior Lecturer, Lecturer I and Lecturer II including those on doctoral training. At least three respondents were proportionately selected from each group. For chemistry option stratum, all options in chemistry which are: polymer, analytical, organic, industrial, and nanochemistry and so on were proportionately sampled across the two groups by rank.

3.4 Research Collection Instruments

The following instruments were used for data collection:

i. **Interview Schedule –** this instrument was used to determine the data management perceptions of chemists and available management support for research data services. The analysis helpedto answer Research Questions 1, 2 and 4.

ii. **Questionnaire–** this instrument was used to conduct technology acceptance testing of the developed data management prototype by chemists in FUTs in Nigeria. The analysis helped to answer Research Question 3.

iii. **Observation Guide** – this instrument was used to identify and ascertain available laboratory equipment and tools in chemistry departments, libraries and ICT Units in FUTs in Nigeria. Analysis of findings helpedto inform the data management model to be developed in answering Research Question 2.

iv. **Record Inspection** – this instrument was used to analyse the content of records such as laboratory notebooks, code books, and personal notes of chemists in FUTs in Nigeria. Analyses of findings also helped to inform the data management model to be developed in Research Question 2.

3.5 Procedure for Data Collection

Data collection for this study was done in three phases, following the evolutionary prototyping as reviewed in Chapter Two:

Phase 1

Requirement Gathering for Prototype Design– this was done at first visit to the various FUTs in Nigeria so as to provide answer to research questions one and two. The aim was to study the data management perceptions of chemists at workplace and determine the awareness and support systems expected from the university management, research offices, information technology service units and the library on research data management. Qualitative data was gathered during the visit. For qualitative data, semi-structured interview schedule, observation guide and records inspection (please see Appendices) was conducted on the selected chemists, university librarians, directors of information technology service units, and directors of research and development units in their workplace. Data gathered from the visit informed the next stage of the study.

Phase 2

Building the Prototype- The studied data management practice of researchers in the workplace was represented diagrammatically using a Data Flow Diagram (DFD) and other Unified Modelling Language (UML) diagrams. The UML diagrams showed at a glance how the different identified entities and processes in data management worked together towards achieving a common goal. Also, hardware, software, security and other requirements for a successful prototype were stated here.

Then, the data management prototype was developed using JAVA and MySQL, the programming languages of choice for the study.

3.6 System Design

The proposed computer-based data management model followed the evolutionary prototype design method as shown in Figure 3.1:

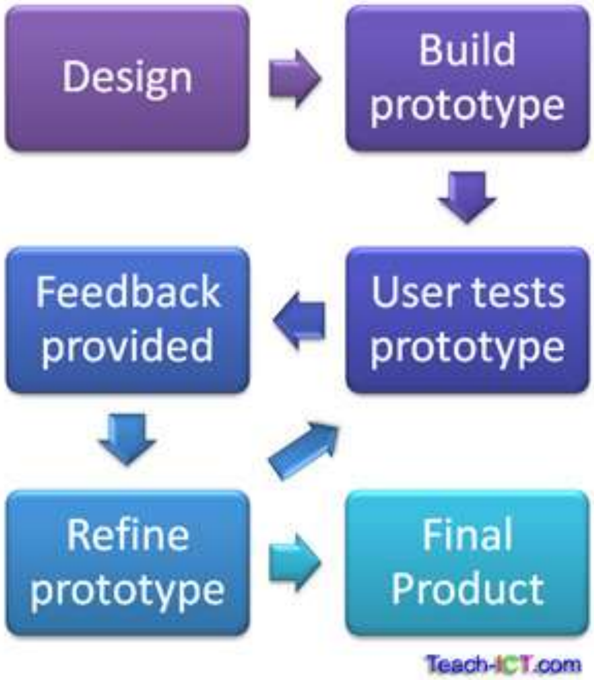


Figure 3.1: Evolutionary Prototype

The Unified Modelling Language (UML) is used to show the design of the research data management system.

3.6.1 Unified modelling language

The Unified Modelling Language (UML) is a language for visualising, specifying, constructing, documenting the artifacts of a software-intensive system (Ceta, 2018). It is a language that provides a vocabulary and the rules for combining words in that vocabulary for the purpose of communication. A modelling language is a language whose vocabulary and rules focus on the conceptual and physical representation of a system. A modelling language such as the UML is thus a standard language for software blueprints.

Unified Modelling Language is a graphical notation for drawing diagrams of software concepts. One can use it for drawing diagrams of a problem domain, a proposed software design, or an already completed software implementation. Modelling is a central part of all the activities that lead to the deployment of good software. Models are built to communicate the desired structure and behaviour of the system; visualize and control the system's architecture, and to better understand the system in order to expose opportunities for simplification and reuse. Models are also built to manage risk.

3.6.2 Unified modelling diagrams

The proposed computer-based data management model developed by this study is called the Chemistry Research Data Management System (otherwise known as ChRDMS) and the following diagrams present the modelling of the system:

i. Users' Process Modelling and Design (Use Case Diagram);

ii. Input/Output Modelling and Design (Activity Diagram);

iii. System Security Modelling and Design (Activity Diagram);

iv. Application Sequence diagram;

v. System Flowchart and Data Flow Diagram (State Chart Diagram);

vi. Database Modelling and Design.

3.6.3 Users' process modelling and design

The ChRDMS is composed of two sub-systems (or component-modules): the chemists' module and the admin module. The Use Case Model diagram in Figures 3.2 and 3.3 shows the way each of these categories of users interacts with the system.

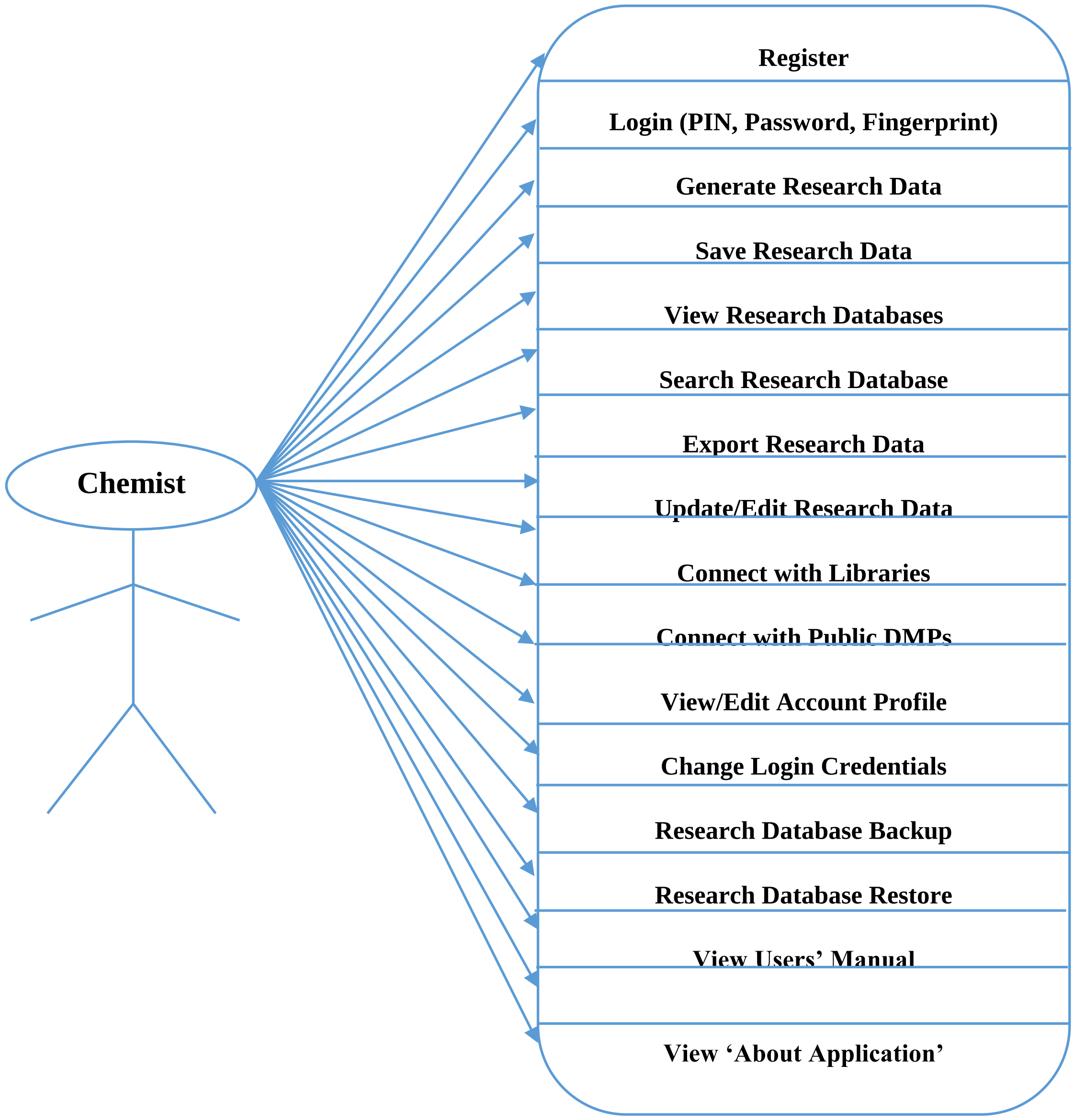


Figure 3.2: Use Case Diagram for Chemists

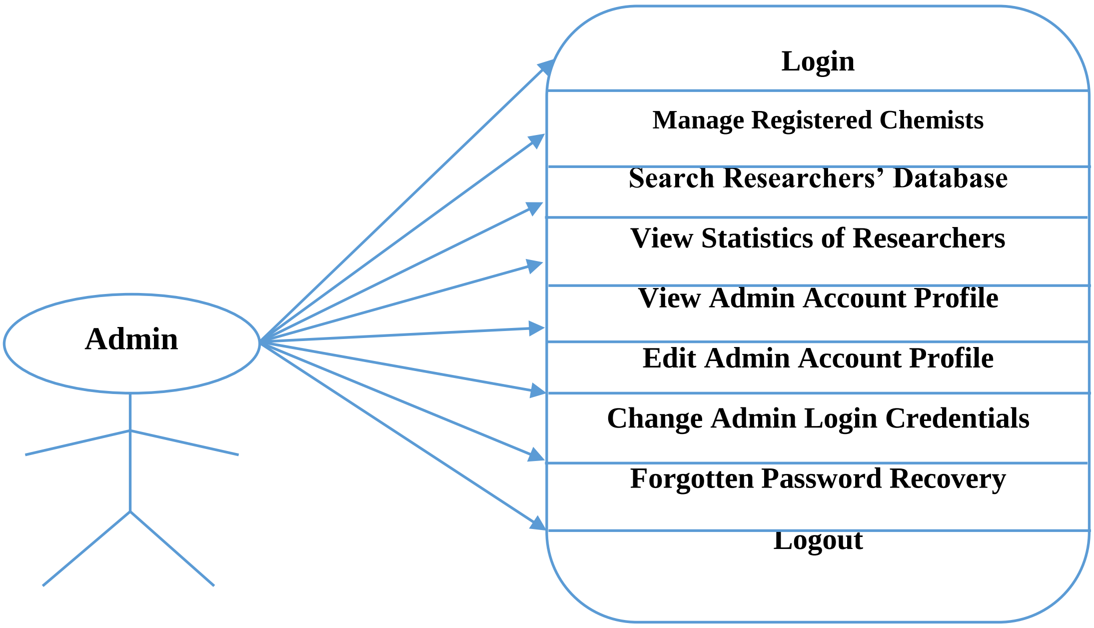


Figure 3.3: Use Case Diagram for Admin

3.6.4 Input/ output modelling and design

The input for the application varies from entering text directly from the keyboard, selecting sets of options from a menu using the mouse, uploading sample images and research documents, uploading files from storage devices and fingerprint enrolment from a fingerprint scanner/reader. The output on the other hand could be in the form of printed outputs (reports) in PDF format, MySQL backup file and zip file, screen display and audio/sound outputs. Both the input and output for the application undergo some kinds of validation and testing to avoid error before the actual processing, as shown in the design model in Figure 3.4 and 3.5 respectively:

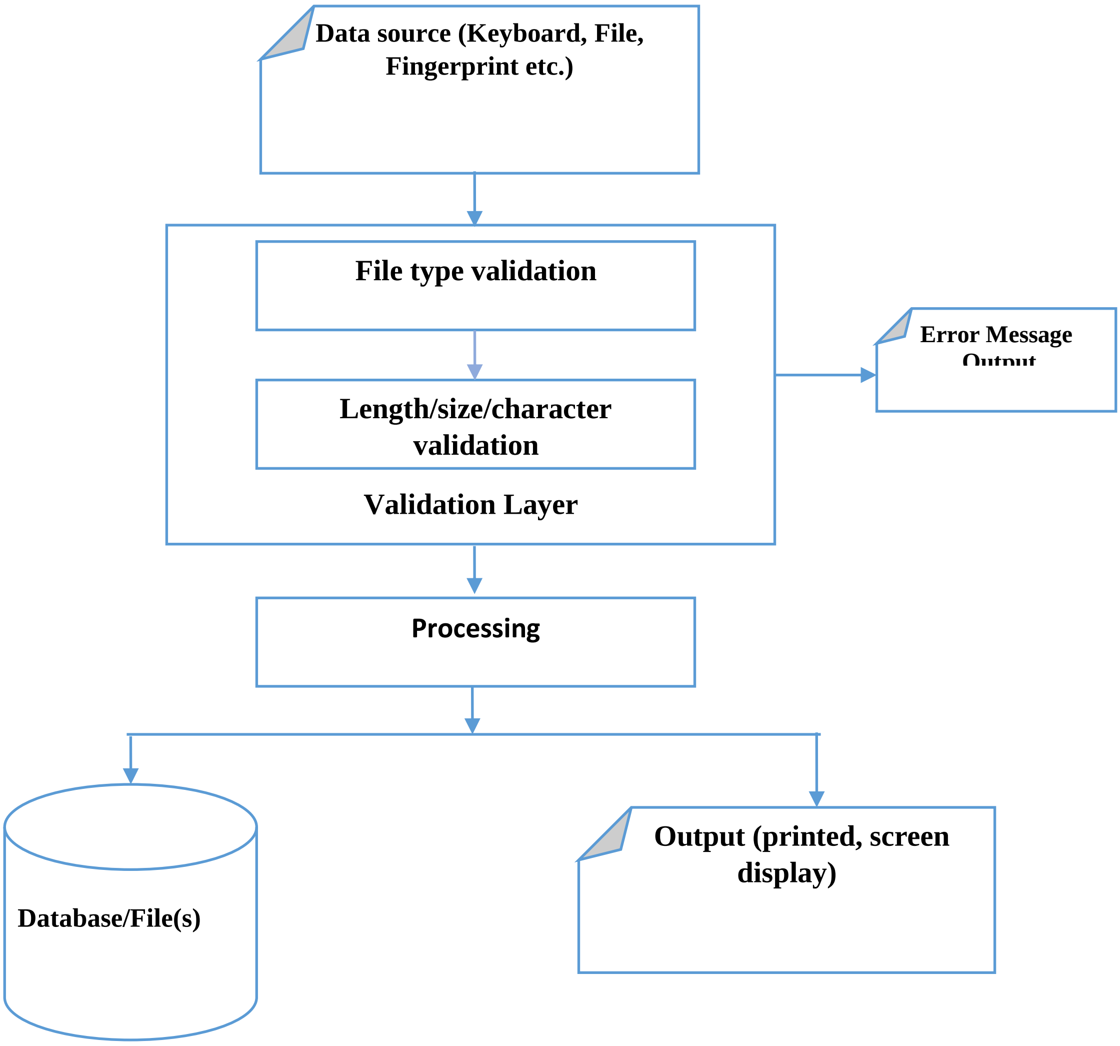


Figure 3.4: Activity Diagram for Input Model

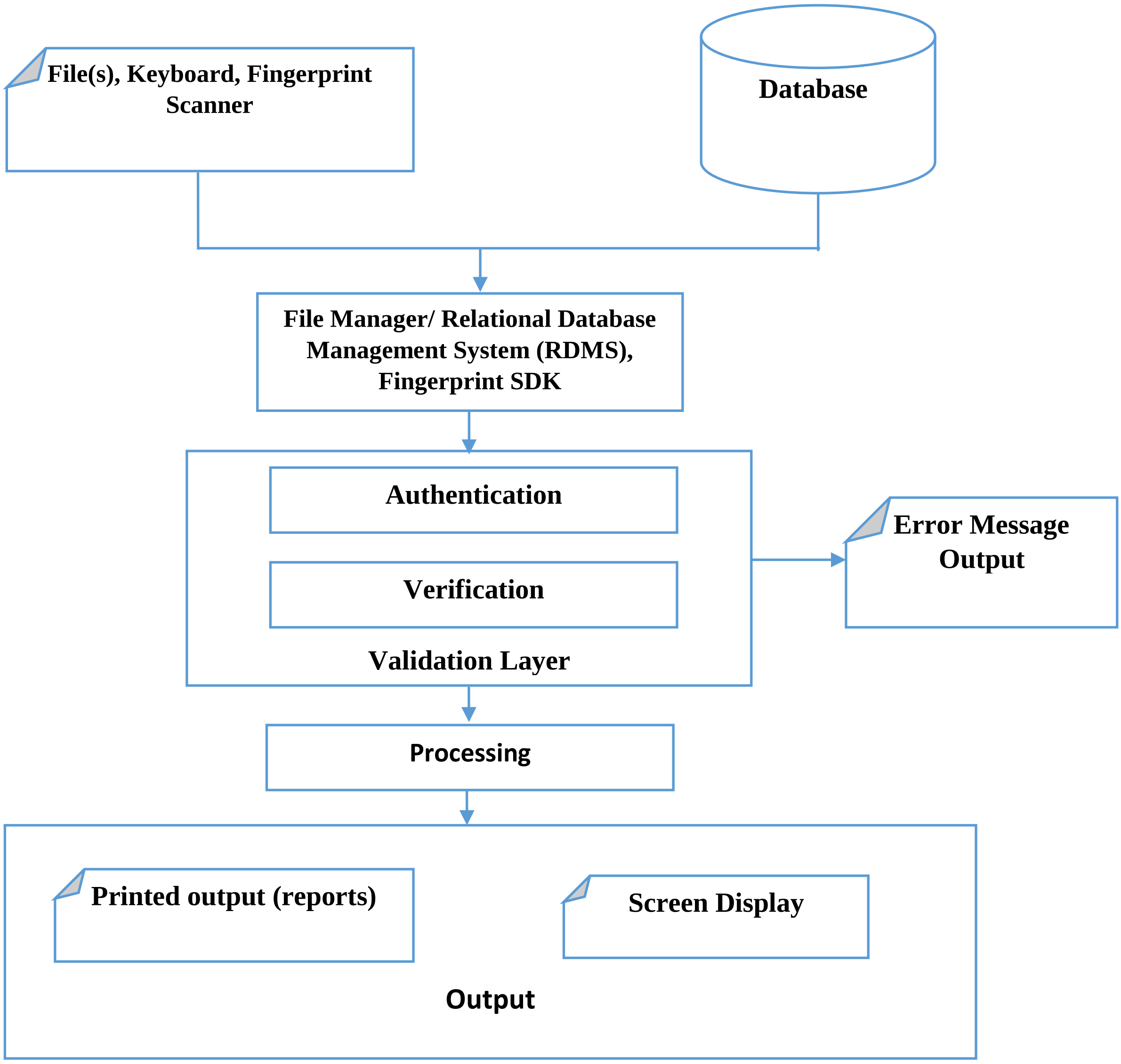


Figure 3.5: Activity Diagram for Output Model

3.6.5 System security control modelling and design

System security control model deals with the control of access to the application. Access to the system requires a unique Personal Identification Number (PIN), user name and password or fingerprint access. These are the security controls of the system for authenticating users before full access is granted to the application. Figure 3.6, shows the model and design of the system security control, while Figures 3.7, 3.8 and 3.9 (a-c) shows the application sequence diagram, system flowchart, and context diagrams with two levels respectively:

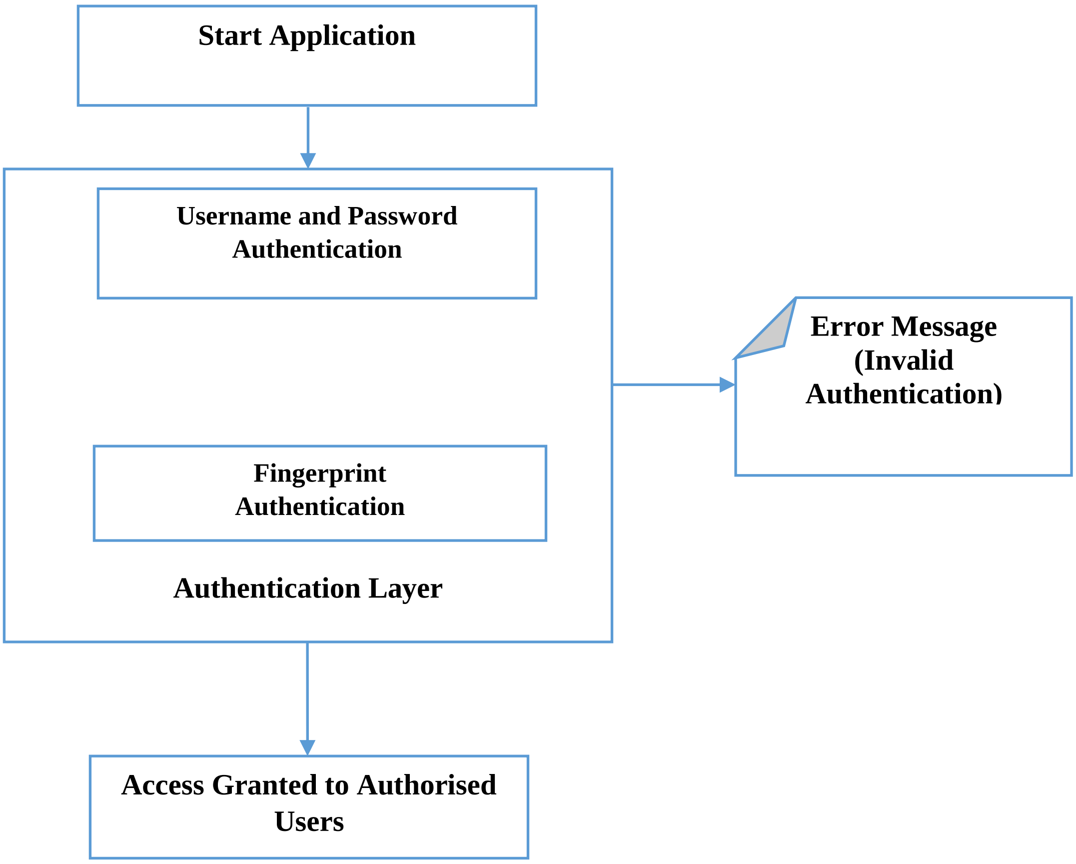


Figure 3.6: System Security Control Model

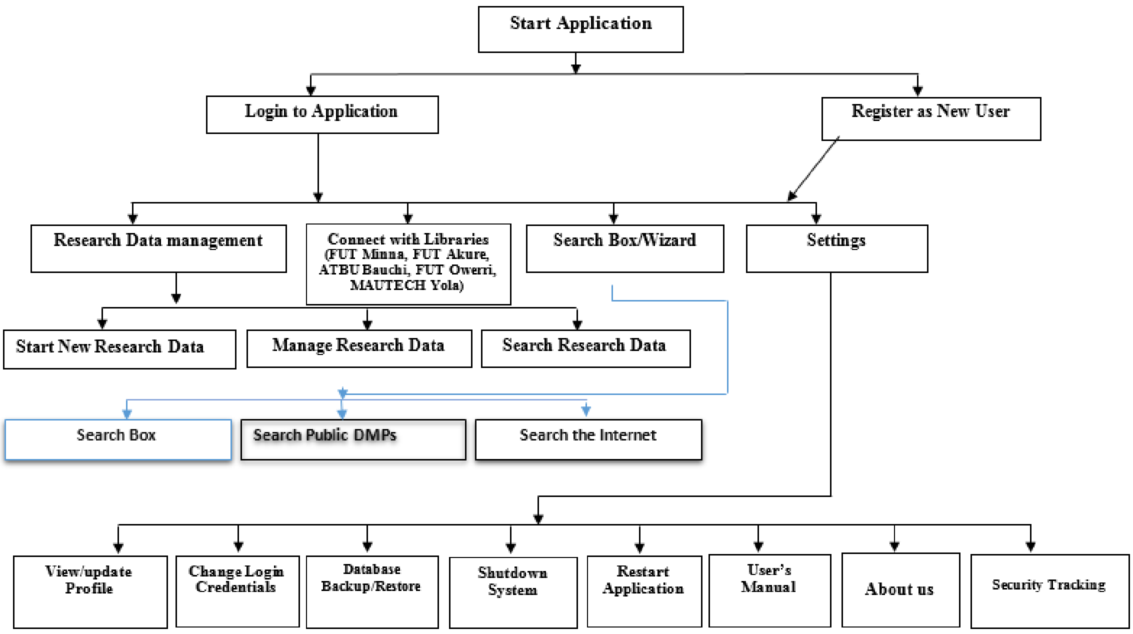


Figure 3.7: Application Sequence Diagram

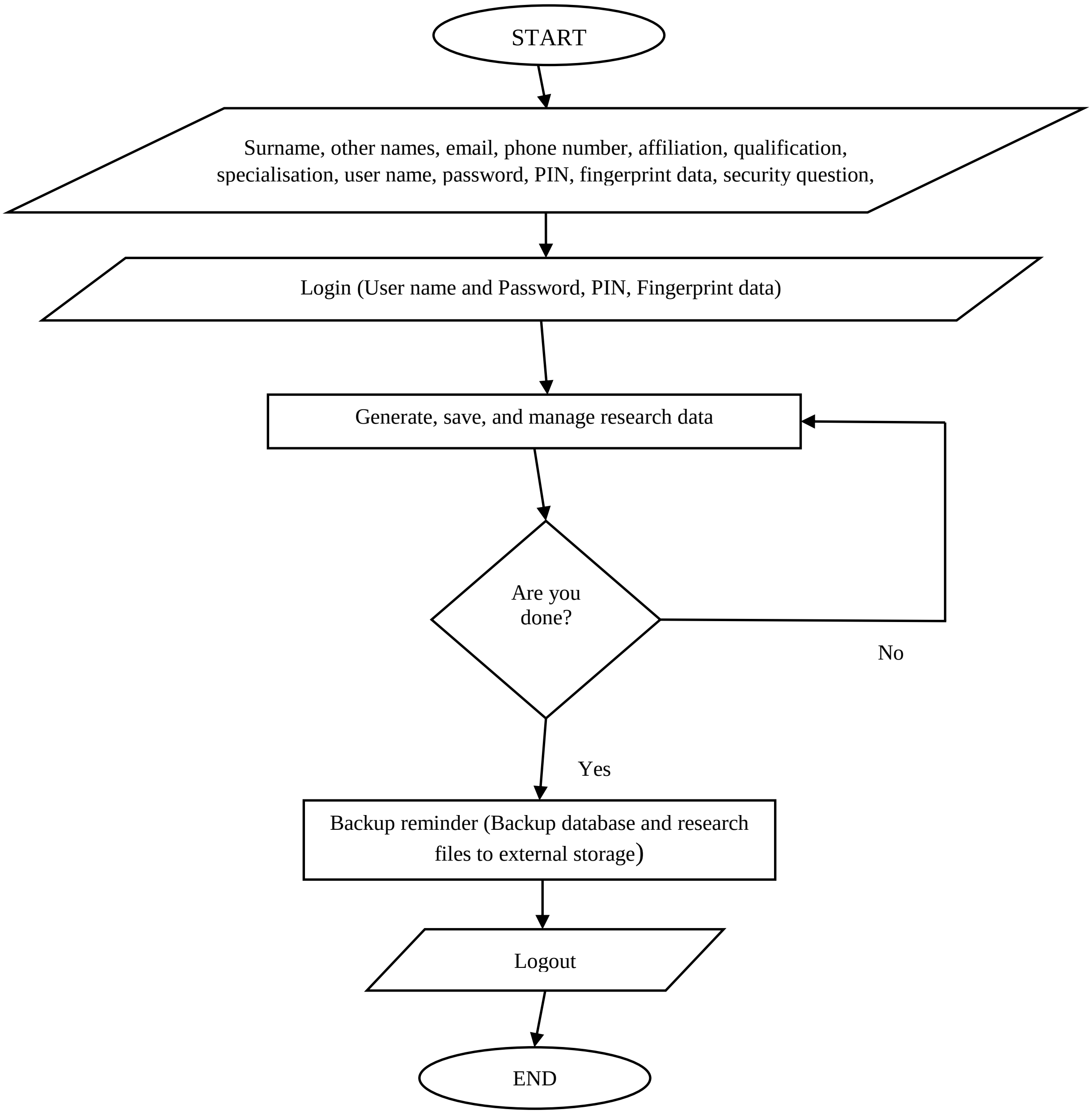


Figure 3.8: System Flowchart (State Chart Diagram)

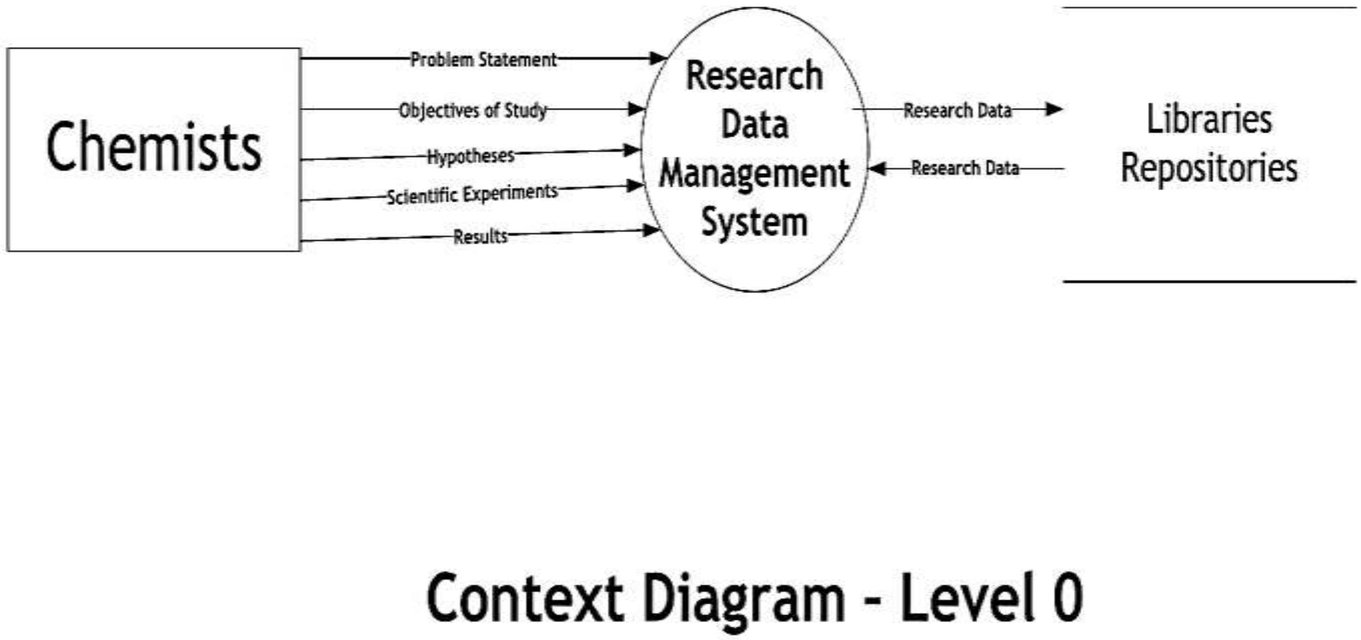


Figure 3.9a: Context Diagram – Level 0

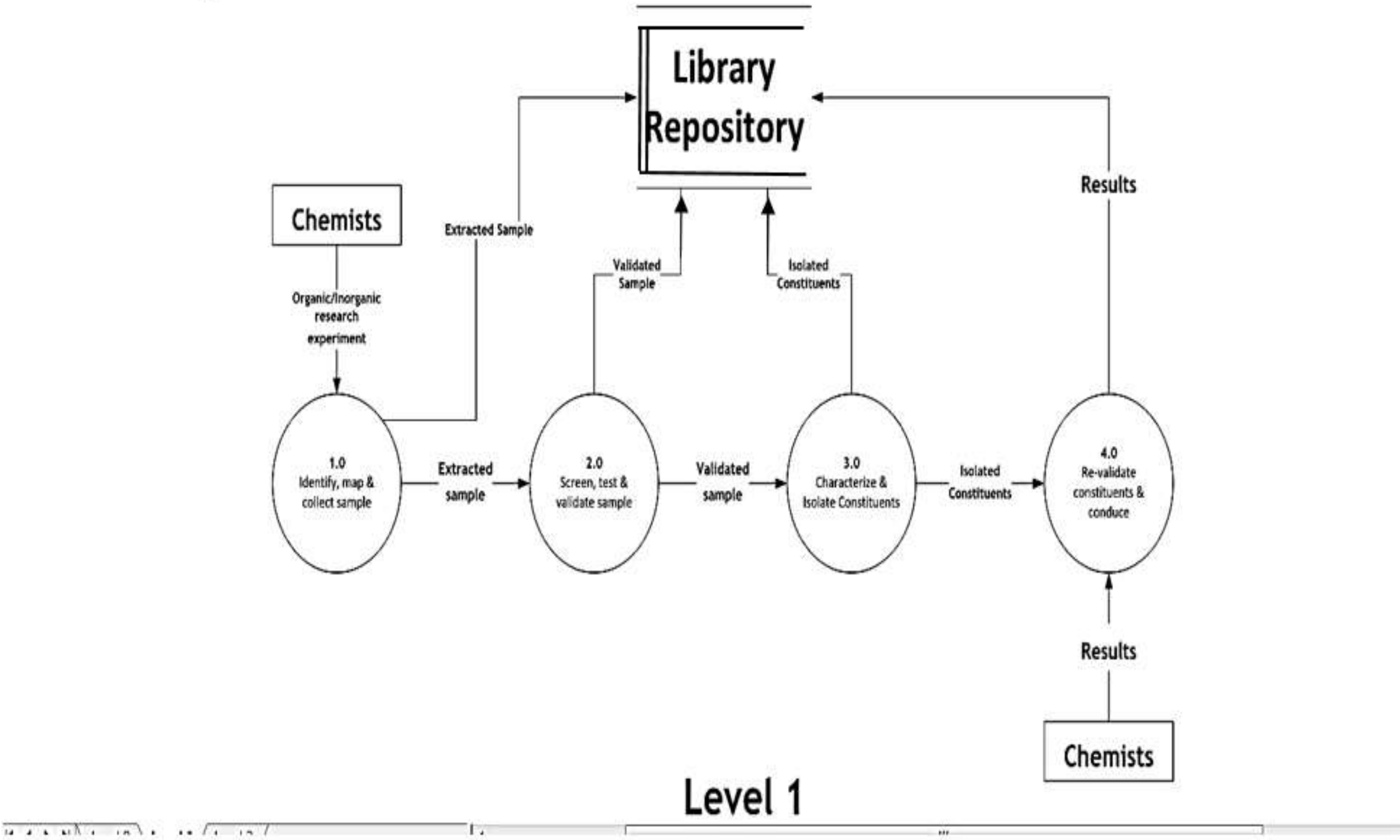


Figure 3.9b: Level 1 Diagram

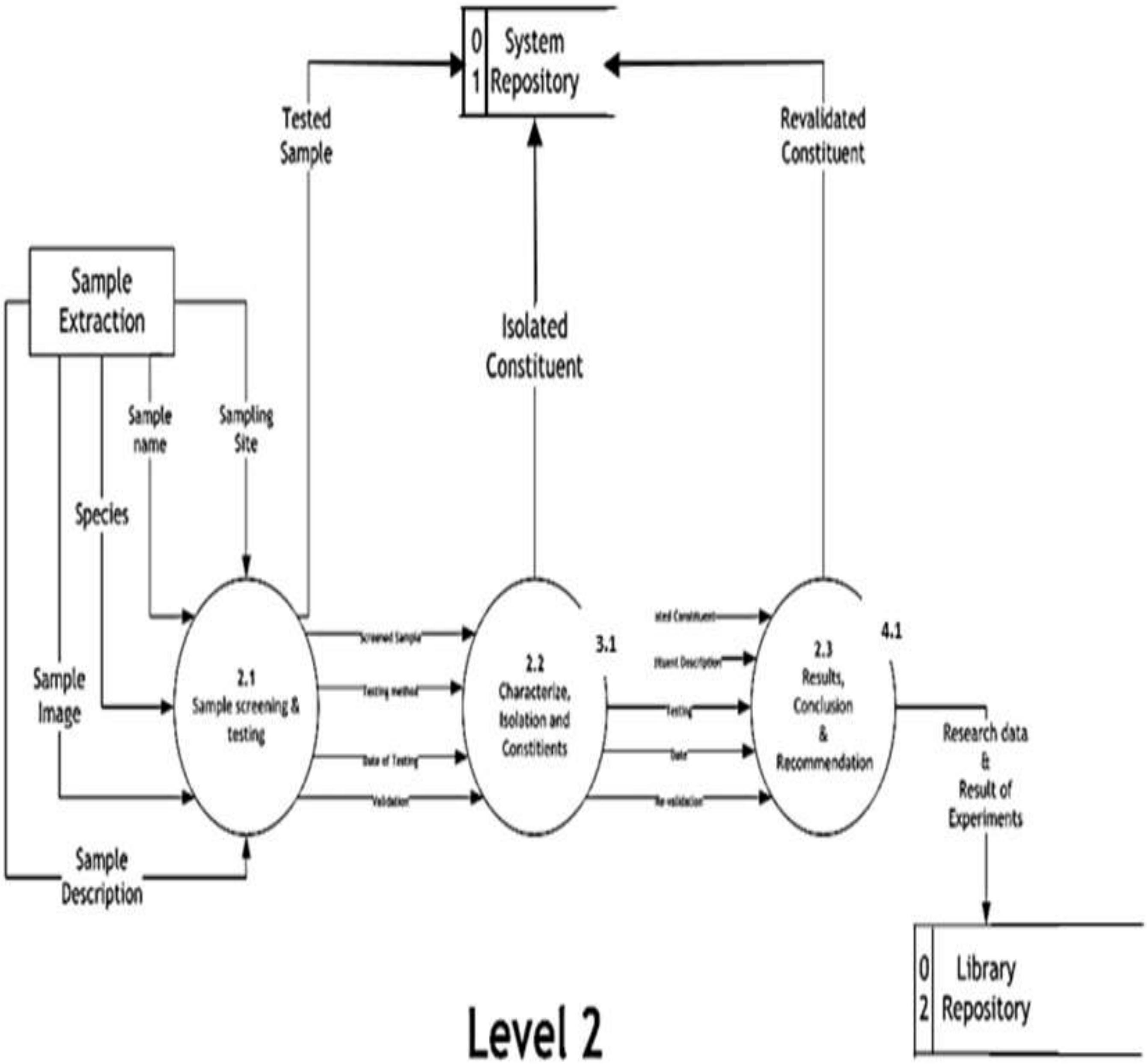


Figure 3.9c: Level 2 Diagram

3.6.6 Database modelling and design

Tables 3.2 to 3.9 shows the data items that were captured in users' account, security tracking, organic/inorganic research data, industrial/polymer/geo/petroleum research data, nano chemistry research data, analytical/food/physical research data, environmental chemistry, and computational chemistry research data.

Table 3.2: Users' Account Table

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
Surname	varchar(15)	-
other_names	varchar(15)	-
Email	varchar(30)	-
phone_number	varchar(15)	-
Passport	blob(5000)	-
PIN	varchar(10)	-
pin_salt	varchar(10)	-
Username	varchar(10)	-
Password	varchar(15)	-
password_salt	varchar(15)	-
fingerprint_data	blob(5000)	-
Affiliation	text	-
Qualification	varchar(10)	-
Specialisation	varchar(15)	-
security_question	varchar(100)	-
security_answer	text	-

Table 3.3: Security Tracking

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
time_in	date	-
time_out	date	-
Name	varchar(20)	-
Email	varchar(30)	-
phone_number	blob(50000)	-
Activity	text	-

Table 3.4: Organic/Inorganic Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
sample_table_name	varchar(20)	-
testing_table_name	varchar(20)	-
constituent_table_name	varchar(20)	-
Results	text	-
Conclusion	text	-
Recommendation	text	-

research_documents	text	-

Table 3.5: Industrial/Polymer/Geo/Petroleum Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	Text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
sample_table_name	varchar(20)	-
treatment_table_name	varchar(20)	-
Results	text	-
Conclusion	text	-
Recommendation	text	-
research_documents	text	-

Table 3.6: Nano Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	Text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
synthesis_table_name	varchar(20)	-
Results	text	-
Conclusion	text	-
Recommendation	text	-
research_documents	text	-

Table 3.7: Analytical/Food/Physical Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	Text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
sample_table_name	varchar(20)	-
pulverisation_table_name	varchar(20)	-
Results	text	-
Conclusion	text	-
Recommendation	text	-
research_documents	text	-

Table 3.8: Environmental Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	Text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
sample_table_name	varchar(20)	-
extraction_table_name	varchar(20)	-
Results	text	-
Conclusion	text	-
Recommendation	text	-
research_documents	text	-

Table 3.9: Computational Chemistry Research Data

FIELD NAME	DATA TYPE	DESCRIPTION
Sn	int(10)	Primary Key
research_type	varchar(20)	-
title_of_research	text	-
sub_title	text	-
research_funder	varchar(20)	-
research_manager	varchar(20)	-
Abstract	text	-
Keywords	Text	-
statement_of_problem	text	-
Objectives	text	-
research_questions	text	-
Hypotheses	text	-
expected_outcome	text	-
problem_formulation	text	-
problem_simulation	text	-
software_used	text	-
result_interpretation	text	-
Results	text	-
Conclusion	text	-
Recommendation	text	-
research_documents	text	-

3.7 System Development

In developing the ChRDMS, the following are the required minimum requirements for Windows®, Linux & Mac-OS:

- Windows, Linux, Unix, Apple and all operating system compatible with Java VM can run the application;
- 2 GH processor or faster (for optimum performance);
- 2 GB RAM or more (for optimum performance);
- 1GB free hard disk space or more;
- Compatible mouse.

Other accessories required for maximum benefit and utilisation of the application are:

- USB fingerprint reader/scanner (optional)
- Printer for printing research data as need arises
- External flash drive or hard disk for backup

Furthermore, the ChRDMS requires the installation of the following programmes:

- Java Runtime Environment (JRE) – 7 (x64 or x32)
- MySQL Database Server
- DigitalPersona Fingerprint SDK

3.8 System Installation

The following steps are required to install and run the Research Data SMS application:

- Install ***Java Runtime Environment (JRE or JDK),*** version 7 or above (x64 or x32)
- Install ***MySQL Database Server***
- Go to your programs' menu/list and open/run the '***MySQL Server Instance Configuration Wizard***'

- Configure your MySQL Database Server with '**3307**' as the port number and use '***security_$_2018data'*** as your password.
- Install the '***DigitalPersona Fingerprint SDK'***
- Install the application '***Research Data Management System'*** connect to the Internet to register for the first time. *Note: after the first time registration, all other activities are done without Internet access.*
- Secure your research data and enjoy the application!

Phase 3

Technology Acceptance Testing- the need for a second visit to FUTs in Nigeria arose here. The developed data management prototype was tested for acceptance by chemists in FUTs in Nigeria. The acceptance testing was done after the *actual use* of the system by chemists in federal universities of technology in Nigeria. Users' feedback was also incorporated and the prototype was refined until a final product was achieved.

Then, a close-ended questionnaire was shared to determine chemists' behavioural intentions towards the continued adoption and use of the data management system. The Study Framework, as adopted from the Unified Theory of Acceptance and Use of Technology (UTAUT) in the previous chapter, was used to determine chemists' behavioural intentions towards use of the system. Finally, a suggested framework on how to implement a sustainable research data management service by libraries in federal universities of technology in Nigeria was proposed for adoption.

3.9 Validity of Research Instruments

Validity is a measure that ensures that constructs used in a research instrument is adequately measuring what it is meant to measure. It is a measure of relevance and adequacy of content of research instrument. Quantitative research instrument like questionnaire are often subjected to validity test. The questionnaire itemsused for this study was subjected to face and content validation by lecturers from General Studies (GST), Chemistry, Science Education, and Library Information Technology departments in Federal University of Technology, Minna.

3.10 Reliability of Research Instruments

Reliability is ensuring that research instruments will measure and give the same results over time.Copies of the questionnaire was shared to seven (17) researchers from Chemistry Department in Ibrahim Badamosi Babangida University, Lapai, Niger State and Cronbach's Alpha statistical tool was used to test the reliability coefficient. The result of Cronbach's Alpha reliability testing gave 0.79 (79%) reliability value (see Appendix K for each constructs' reliability value).This shows that the questionnaire is valid and reliable to be used for this study.

Furthermore, variables of the Unified Theory of Acceptance and Use of Technology (UTAUT) were adopted to formulate questionnaire which was used for technology acceptance testing by chemists. Several studies have adopted this theory which has been validated and deemed reliable (Venkatesh *et al.*, 2003) for studies on technology acceptance (Wu *et al.*, 2008; VanSchaik, 2009; Chao, 2019).

3.11 Hypotheses Testing

Kendall's Tau-b correlation coefficient was used for hypotheses testing on a 0.05 level of significance and questionnaire items were based on a 5-point Likert scale of 'Strongly Agree-Strongly Disagree'. The results were used to determine whether to accept or reject the formulated null hypotheses.

3.12 Method of Data Analysis

For qualitative data transcription and analysis, this study adopted the Braun & Clarke (2006) thematic analysis approach which involves a six-phase of qualitative data analysis. These phases are: transcribing data, generate initial code, search for themes, review themes, define and name themes, and finally present the final report of the analysis.

Data collected from chemists and stakeholders across FUTs in Nigeria were manually transcribed verbatim from the audio recordings. This was followed by the initial coding of the transcribed data. Furthermore, with the assistance of a certified Data Analyst, the *Provalis* Qualitative Data Analysis (QDA) Miner (Version 5) software was used for generating themes and subthemes from the coding framework and the final report was presented.

The *Provalis* QDA Miner is an easy-to-use qualitative data analysis software package for coding, annotating, retrieving and analysing small and large collections of documents and images. QDA Miner qualitative data analysis tool may be used to analyse interview or focus group transcripts, legal documents, journal articles, speeches, entire books, as well as drawings, photographs, paintings, and other types of visual documents (provalisresearch.com).

Statistical Package for Social Sciences (SPSS) version 23 software tool was used to calculate Kendall Tau-b of quantitative data gathered during technology acceptance testing using the UTAUT constructs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Interview response rate

Table 4.1 presents the response rate from the oral face-to-face interview conducted with chemists, university librarians, directors of information technology service units, and directors of research and development units in the five federal universities of technology in Nigeria. The population of this study include only chemists with a doctoral degree or currently undergoing a doctoral training as at the time of data gathering:

Table 4.1: Response Rate across FUTs in Nigeria

S/N	University	Interviewed	%
1.	Abubakar Tafawa Balewa University, Bauchi, (ATBU), Bauchi State.	7	17.5
2.	Federal University of Technology, Akure, (FUTA), Ondo State.	8	20
3.	Federal University of Technology Minna, (FUTMIN), Niger State.	11	27.5
4.	Federal University of Technology, Owerri, (FUTO), Imo State.	8	20
5.	Modibbo Adama University of Technology, Yola, (MAUTECH), Adamawa State.	6	15
	Total Number of Chemists	**40**	**100**
	Supporting Stakeholders across FUTs in Nigeria		
1.	University Librarians	5	100
2.	Directors of ITS Units	5	100
3.	Directors of Research and Development Units	5	100
	Total Number of Supporting Stakeholders	**15**	**100**
	Grand Total	**55**	**100**

Forty (40) chemists were available at the time of interview due to the fact that the others were either on leave of absence, sabbatical, study leave or on government appointment outside the university. However, interviewed chemists covered all options in chemistry available in the federal universities of technology in Nigeria.These options are:

- Analytical Chemistry
- Computational Chemistry
- Environmental Chemistry
- Food Chemistry
- Geochemistry Chemistry
- Industrial Chemistry
- Inorganic Chemistry
- Nano Chemistry
- Organic Chemistry
- Petroleum Chemistry
- Physical Chemistry
- Polymer Chemistry

The rank of interviewed chemists also covered those with doctoral degree or currently undergoing a doctoral training. These ranks are:

- Professor = 6
- Associate Professor/Reader = 10 } Group 1 = 16

- Senior Lecturer = 10
- Lecturer I = 5 } Group 2 = 24
- Lecturer II = 9

All the fifteen supporting stakeholders were available and interviewed accordingly.

Table 4.2 shows the breakdown of chemists into ranks:

Table 4.2: Ranking of Chemists across FUTs in Nigeria

S/N	University	Rank of Respondents	Options in Chemistry	Number of Respondents
1.	**ATBU**	Professor – 1 AP/Reader – 3 Senior Lecturer – 2 Lecturer I – 1	Organic, Environmental, Physical, Inorganic, Analytical Chemistry.	7
2.	**FUTA**	Professor – 1 AP/Reader – 1 Senior Lecturer – 2 Lecturer II – 4	Food, Environmental, Petroleum, Geochemistry, Analytical, Industrial, Polymer Chemistry.	8
4.	**FUTMIN**	Professor – 1 AP/Reader – 3 Senior Lecturer – 3 Lecturer I – 2 Lecturer II – 2	Analytical, Polymer, Organic, Environmental, Nano chemistry.	11
3.	**FUTO**	Professor – 2 AP/Reader – 1 Senior Lecturer – 3 Lecturer II – 2	Organic, Analytical, Physical, Environmental, Polymer, Computational Chemistry.	8
5.	**MAUTECH**	Professor – 1 AP/Reader – 2 Lecturer I – 2 Lecturer II – 1	Polymer, Physical, Organic, Environmental, Analytical Chemistry.	6
	TOTAL			**40**

The fifteen (15) supporting RDM stakeholders which are: the university librarians, directors of ITS units, and directors of research and development units, were also interviewed and the results were incorporated in the findings of the study.

4.2 Data presentation and analysis of interview responses

Chemists were interviewed (see Appendix C for interview questions) to determine their data management practices including the processes, methods and tools used when working with data at each stage of their research lifecycle. Their responses were instrumental in answering Research Question 1 which was to determine the data management perception of chemists in FUTs in Nigeria with a view to gatheringrequirements for developing a data management model. Similarly, the supporting stakeholders- University Library, Information Technology Service Unit, and Research and Development Unit involved in research data management, were also interviewed (see interview questions on Appendix D, E, F) to determine the awareness and available support system necessary for the successful implementation of research data management services in their institutions.

Research Question 1: What is the data management perception of chemists in FUTs in Nigeria with a view to gathering requirements for developing a data management model?

4.3 Data management perception of chemists in FUTs in Nigeria

To determine the perception of chemists on research data management and available support systems for RDM from stakeholders in FUTs in Nigeria, a semi-structured interview was conducted on chemists, university librarians, heads of information and technology service units, and heads of research and development units in the five FUTs in Nigeria. It took approximately three months from August to October, 2017, to travel across the four geopolitical zones that have a Federal University of Technology in Nigeria for requirement gathering.

The interview questions for chemists were grouped into sections 1-6 (see Appendix C); while questions for stakeholders can be found in Appendix D, E, F. The interview was oral and face-to-face and responses were recorded using audio recorder. Respondents were given an informed consent form (see Appendix A) to fill in order to assure them of the confidentiality of responses and other related issues. Interviews lasted for approximately thirty minutes while the least response time was about nine minutes depending on the respondents' knowledge of the questions asked. A Research Assistant was employed to assist with the audio recording and to ensure that informed consent forms were properly filled and collected. All interviews were conducted in the respondents' workplace after an agreed day and time which was usually at about 9am-4pm of any working day. The data gathering process took approximately ten weeks (2months and 14days) due to the distance involved in traveling across the six geopolitical zones in Nigeria where the FUTs were located.

For the data transcription and analysis, the study adopted the Braun & Clarke (2006) thematic analysis approach which involves a six-phase of qualitative data analysis. These phases are: transcribing data, generate initial code, search for themes, review themes, define and name themes, and finally present the final report of the analysis.

Data collected from chemists and stakeholders through interview across FUTs in Nigeria were manually transcribed verbatim; this was followed by the initial coding of the transcribed data. In addition, with the assistance of a certified Data Analyst, the *Provalis* Qualitative Data Analysis (QDA) Miner (Version 5) software was used for generating themes and subthemes from the coding framework and the final report is presented in section 4.4 below.

The *Provalis* QDA Miner is an easy-to-use qualitative data analysis software package for coding, annotating, retrieving and analysing small and large collections of documents and images. QDA Miner qualitative data analysis tool may be used to analyse interview or focus group transcripts, legal documents, journal articles, speeches, entire books, as well as drawings, photographs, paintings, and other types of visual documents (*provalisresearch.com*).

4.3.1 Presentation of result- Research Question 1

The interview schedule used for understanding data management perception of chemists was divided into six sections and coded responses were analysed and arranged into themes and subthemes using the *Provalis* QDA Miner. Figure 4.1 shows the major themes derived from the data analysis. These themes were further discussed under the six sections of the interview schedule.

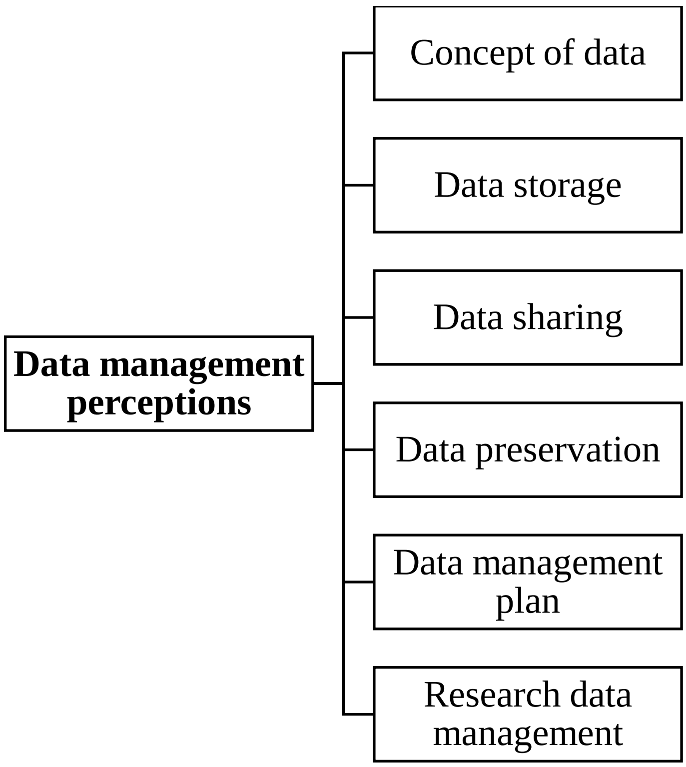


Figure 4.1: Thematic Diagram of Data Management Perceptions of Chemists in FUTs in Nigeria

Section 1 – Concept of data

This section revealed chemists' understanding of data and research data and how they create and manage digital data and files, the techniques developed to organize, format and record the details of research data as well as data loss experiences. Figure 4.2 shows the sub-themes under the concept of data as perceived by the chemists:

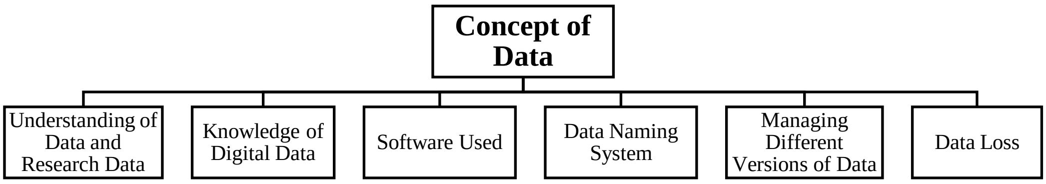


Figure 4.2 Data Concept by Chemists

i. Understanding of data and research data

Chemists in FUTs in Nigeria defined data and research data based on their understanding of the concepts. In ATBU Bauchi, chemists saw data as a sequence of numbers or figures derived from experiments which could be used for validation. Research data, are however, seen as data from research work. Chemists in FUTA saw data as collection of facts gathered from experiments while research data are generated from such experiment conducted in a laboratory. Chemists from FUTMIN defined data as results gathered from investigations while research data is seen as facts acquired from research. Chemists in FUTO defined data as results of experimental studies presented in figures, results of experiments, collection of information gathered to enhance research, facts, quantifiable results as well as results obtained from quantitative or qualitative analysis. Research data however is seen as results obtained from research studies in the laboratories, or from a systematic study which could be intermediate or final derived during the research. Chemists in MAUTECH defined data as valuable resources to get results, a set of figures, information collected for the purpose of studying, any information in bits, groups, or quantity that can be processed further. Research data on the other hand is seen as outcome from research, set of figures collected in the field, data obtained from experiment that is aimed at getting results, and data used for finding out things.

Chemists generally agree that research data is “any information gathered before, during and after an experiment or research”, and it can be in different forms- pictures, numbers, figures, texts, graphs. In ATBU Bauchi, chemists’ research data are in the form of experimental data, field data, and observation, physical and chemical data. FUTA chemists research data types are laboratory data, environmental data, and primary data. In FUTMIN, research data could be experimental data, primary, secondary, plant, human, geographical, field, or statistical data. FUTO research data types are laboratory data, experimental data, conceptual data, simulation data, field, empirical, and data from questionnaire. The different types of research data according to MAUTECH chemists include plant data, field data, laboratory data, experimental data, questionnaire, interview, and archived data. This shows that a large percentage of chemists have an understanding of what research data is and the most common research data types are: experimental data, laboratory data, questionnaire data, interview data, field data, and plant data. This is further depicted in the word cloud of Figure 4.3. A word cloud is simply an image composed of words in a particular text or subject, in which the size of each word indicates its frequency or importance.

Figure 4.3: Word Cloud showing Chemists understanding of Data and Research Data

ii. Knowledge ofdigital data

ATBU chemists generate and use digital data based on the research being carried out. These digital data are mostly in the form of graphs, images, MATLAB, and NMR Spectra. Chemists in FUTA also generate and use digital data. Their digital data are in the form of spreadsheets, texts, images, NMR spectroscopy, and graphs. FUTMIN chemists generate digital data which are usually in the form of spreadsheet, text, image, video, Matlab, NMR spectroscopy, graphs, Thin Layer Chromatography (TLC) and other customized files from instrument-specific software. For FUTO chemists, digital data generated could be in the form of graphs, spreadsheets, images, tables, MATLAB (matrices), and texts. Chemists in MAUTECH all generate digital data which were mostly in the form of spreadsheets, images, figures, charts, NMR spectra, scanned documents, and graphs.

All chemists are knowledgeable about digital data which are usually in the forms presented in the *word cloud* below. Spreadsheets and NMR spectra are the most common types of digital data generated by chemists in FUTs in Nigeria. This is shown in Figure 4.4.

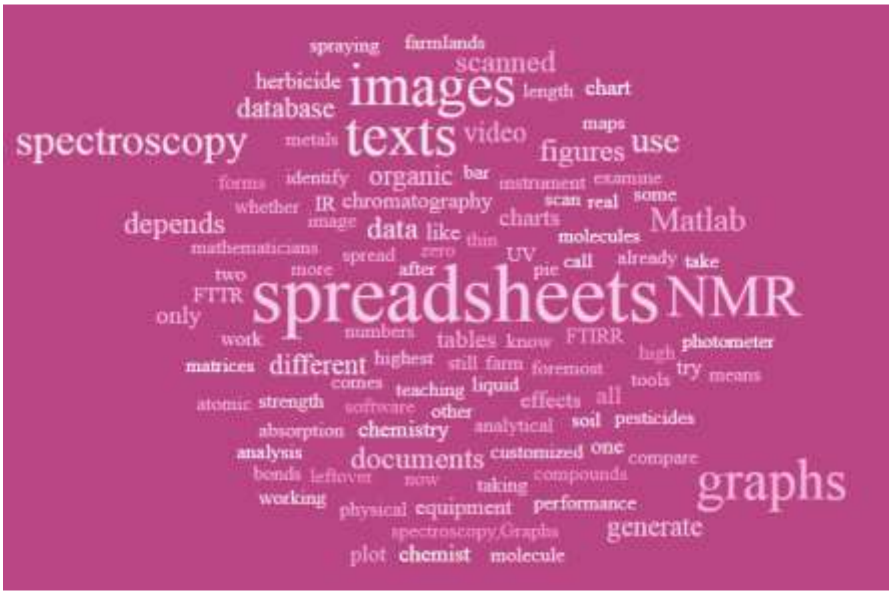


Figure 4.4: Word Cloud showing Types of Digital Data

iii. Software used for digital data generation

In ATBU Bauchi, some of the software used for digital data analysis are Minitab, SPSS, Origin 8, Origin 10, CHEMSK, Material Studio, ACCRYLS. In FUTA, software mostly used for analysis are Microsoft Excel, SPSS, and NMR spectrometry. In FUTMIN, software used for digital data generation and processing include Origin, Minitab, Matlab, SPSS, MS Excel, ChemDraw, PLS, QSAR and MS Word. Chemists in FUTO use Origin, Microsoft Excel, OriginPro, MATLAB, electrochemical data equipment software, OGR, SPSS, ArchView, AquaChem, MudFlow, QTIPLOT, Zigmaplod, and Artificial Neural Network (ANN) software. In MAUTECH, software used for data generation are ChemDraw, ChemSketch, UC Spectra, instrument-specific software, SPSS, UC machine software, Aurora.

SPSS is the most common software used for digital data generation as depicted in the word cloud in Figure 4.5:

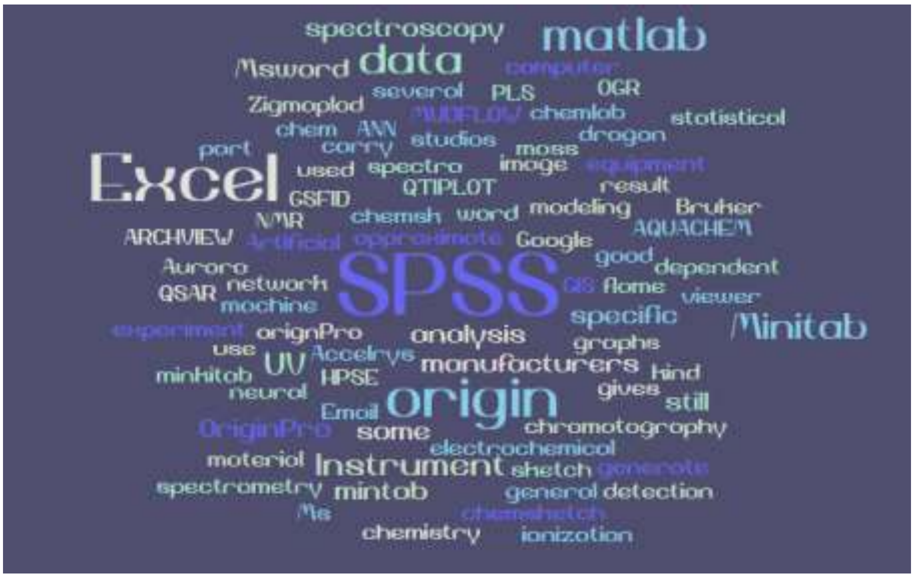


Figure 4.5: Word Cloud showing Software for Digital Data Generation and Analysis

iv. Data naming system

Chemists in ATBU Bauchi store and name data using the source, name, title, codes, and date. In FUTA, data are stored and named using self-devised names, research-dependent names or just sample name. They also use defined abbreviations and codes for saving files and data. FUTMIN chemists store and name digital data files using date and day of data generation, name of researcher, name of sample, site name, codes, and any other convenient self-devised means. Chemists in FUTO do not have any specific naming convention as data are stored and named based on the current research, self-devised, use of date, time and year, researcher's middle name, student's name generating the research, instrument used for analysis, experiment-based, and location of research sample. However, to identify different versions of stored files, chemists in FUTO make use of number, day of research, storing on different CDs/flash, number of runs, dates, and current research result. For MAUTECH chemists, digital data files are stored using random self-devised methods based on the research. Dates, initials, numbers, use of children's names, acronyms, codes and condition of experiment are used to store different versions of digital data on the system.

A researcher from ATBU opined that:

"*It depends on the data I have, I just name from the source.*"

While from FUTMIN:

"I use date, day, name of researcher, coding"

"I use my name, if I open my computer you'll see [researcher's name] 2010"

Another researcher from FUTA said:

"*I can use anything, sometimes I can use my name, I can use the name of my son, it depends on what I wantto name*"

In storing research data, devising a distinct naming style is of utmost importance to aid retrieval of data files. This sub-node uses bar chart to show methods used by chemists in saving their digital data files as shown in Figure 4.6.

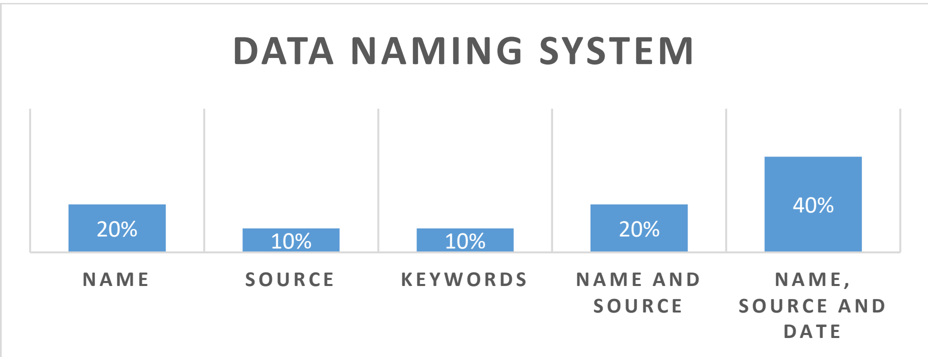


Figure 4.6: Data Naming System of Chemists in FUTs in Nigeria

v. Managing different versions of data

Chemists in ATBU Bauchi manage different versions of stored data by using NMR-specific numbers, UV-generated numbers, self-devised numbers and codes. Other details of stored data files are generated by the computer automatically. To identify different versions of stored files, chemists in FUTO make use of number, day of research, storing on different CDs/flash, number of runs, dates, and current research result. Chemists in FUTMIN and MAUTECH manage different versions of data using folders and other details are generated by the computer system automatically.

vi. Data loss

Interestingly, chemists in ATBU agreed that they have at one time or the other experienced a data loss situation. This was as a result of storage device theft, computer system malfunction, and sudden file corruption. Although some of the chemists were able to manage the situation because they had backup on an external drive while majority said they lost such files completely. Most chemists in FUTA have had painful experience of data loss which was as a result of not saving while working on the system, corrupted files copied from an external device, and sudden system crash. Regular backup and continuous saving while working are lessons learnt from the sad data loss experience. Chemists in FUTMIN agreed to have lost critical and often irrecoverable data due to poor storage device, system crash, bad memory card, virus attack, and system theft. Lessons learnt from data loss experience included using clear labels and names for stored data files, backup data in multiple locations, proper handling of external storage devices, seeking help from computer specialists when confronted with system faults, adopting online storage and cloud services. Only one chemist in FUTO has never experienced a data loss situation due to poor file storage, unrecognized file format or bad storage device. Others have had the unfortunate experience due to damaged external hard disc, power failure while conducting an experiment, spoilt flash drive, corrupted files, system crash, system theft, and data loss in the process of upgrading from one software or system to the other. Lessons learnt from these experiences are regular backups, constant file saving while working, and creating backup in multiple locations. All MAUTECH chemists have experienced data loss due to poor file storage, unrecognized file format or bad storage device. This usually happens as a result of system crash, system theft, and sudden corruption of system, improper file naming, virus attack, and system malfunction. Lessons learnt from the unfortunate incidence include the need for external backup, sharing and storing in different places, patience while saving files, and proper security of stored data.

Chemists' experience on data loss was supported by Gonzalez & Peres-Neto (2015) where it was observed that "information is lost when researchers fail to store, archive or share their data; this could be as a result of ageing technology or corruption of data-storage devices''.

A chemistry researcher from ATBU shared that:

"Serious! what happen actually was as I took my data and have been recording in the storage machine thenI connected the computer to another machine that is supposed to display the work from scratch and somehowI don't know what happened but it affected the computer and I could not see the data but fortunately I hadsome back up but not all. I was forced to go back and repeat the experiment for latter part of the work".

Another research data loss experience from a chemistry researcher in FUTA was that:

"*…in fact something happened yesterday, I don't know (giggles), my existing file, all of a sudden, I just sawsomething like that, like Arabic something or no no Chinese, I don't know the type of language something, Aahh! I hopethis is not virus! I closed it and opened it and everything was gone."*

Lessons learnt from the unfortunate incidence include the need for external backup, sharing,updating and storing in different places, patience while saving files, and proper security of storeddata.

Section 2 – Data storage

This section shows how chemists decide on the storage media type to use and their backup methods. Figure 4.7 show the subthemes under the data storage as perceived by the chemists:

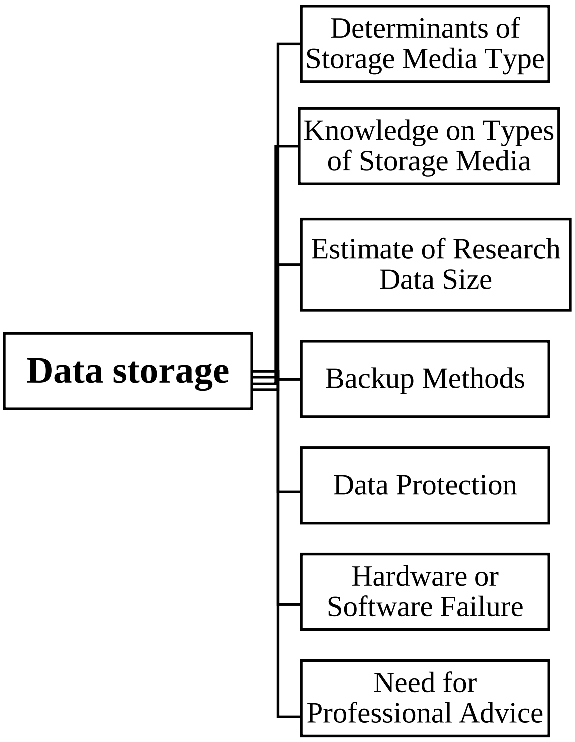


Figure 4.7 Perception of Data Storage by Chemists in FUTs in Nigeria

i. Determinants of storage media type

Where research data is stored is vitally important for current and future use. Improper and/or insecure data storage locations can lead to data loss, theft, deletion, and a plethora of complexities if not stored in stable, secure, and reliable locations (Smith, 2014).

According to ATBU chemists, storage media to be used for managing research data depends on the value of work done, however, the most important factor in determining storage media is security. For FUTA chemists, the choice of storage media to use for storing data is dependent on the portability, accessibility and safety from virus of the storage media device. Factors that affect FUTMIN chemists' choice of storage device include portability, durability, accessibility, security, mobility and reliability. Preferred choice of storage device are external hard discs and online storage such as drop box, email, Google drive, depending on the volume of the work. Chemists in FUTO consider the following when deciding on the storage media to use- durability, storage capacity, and portability, susceptibility to virus, ease of retrieval, mobility, and safety. Researchers keep record of stored files and data in office lockers, at home, with a research assistant, and in the laboratory. In deciding storage media to use for data files, chemists in MAUTECH consider cost-effectiveness, nature of the data, security of the media, ease of access, and relevance to research. Other factors include capacity of the storage media, mobility, and susceptibility to virus attack, accessibility, and compatibility.

Most preferred storage devices among chemists computer hard drive, Google Drive, flash disk, CDs, external hard disk. These types of storage solutions limit data sharing and long term preservation (Buys & Shaw, 2015).

Figure 4.8 shows the determining factors and their weight on a word cloud. Size of data, safety, portability, capacity, mobility and ease of use are all factors that chemists consider in selecting a storage media for their research data.

Figure 4.8: Determinants of Storage Media Type

ii. Knowledge on types of storage media

ATBU chemists are aware of the advantages and disadvantages of some storage devices especially external hard disks, flash disks, cloud storage using personal email, and compact discs. They are however not aware of same for other cloud storage devices and services. FUTA chemists are aware of the advantages and disadvantages of various storage media. Most of FUTMIN chemists know the advantages and disadvantages of the different storage devices and media. Majority of chemists in FUTO are aware of the advantages and disadvantages of the different storage media. Only few chemists had little or no knowledge of the advantages and disadvantages of different storage media.

iii. Estimation of research data size

Chemists in ATBU revealed that their research data can grow from megabytes to gigabytes depending on the research and funding capacity. FUTA chemists opined that their data files can also grow to as large as gigabytes depending on the type of research. They also noted that estimating the growth of data files from the beginning of the research is not easy except the research is concluded. The estimated size of research data by FUTMIN chemists were mostly in megabyte, although some research data could run into gigabyte and even terabyte depending on the type of research. Most researchers in FUTO estimated that their research data can grow into gigabytes and even terabytes depending on the type of research. Only one researcher estimated research data to be in megabyte. In MAUTECH, chemists also noted that their estimated file size while conducting research might be in megabyte, although the estimate was not easy to give as it depends on the research being conducted.

Chemists were able to estimate the size of their research data using megabytes, gigabytes and terabytes. However, a large percentage of them could not predict the increase. This means that establishing a correctly sized research storage service will be difficult (Buys & Shaw, 2015). The proportion of chemists that could predict data increase is as described in Figure 4.9:

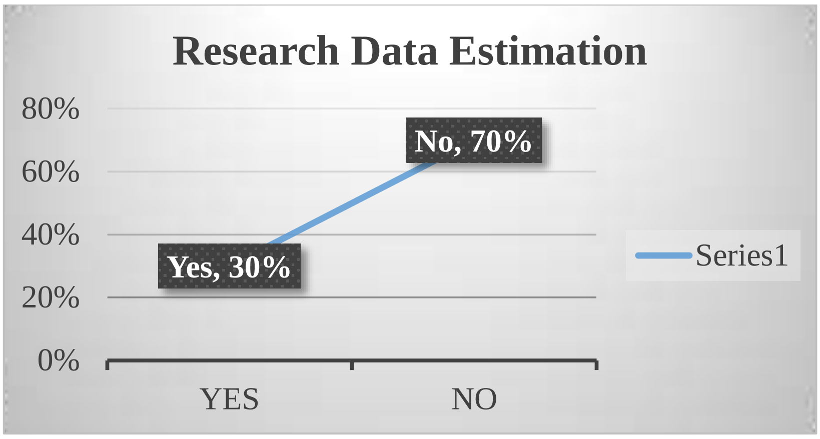


Figure 4.9 Estimation of Research Data Size

iv. Backup methods and additional storage device

Backup method of ATBU chemists is to update data saved on external devices regularly. FUTA chemists perform updating and backup of data files occasionally either on the master file only or on all other files stored in various locations. In FUTMIN, chemists adopt periodic update of files on their local system, upload to cloud storage devices, use of external hard disks as well as automatic backup. Only few researchers do not engage in periodic update of files and data. Additional storage device mostly used include system hard disk, CDs/DVDs, flash sticks, hard copies and cloud storage. FUTO chemists backup their data as the research is ongoing, they also use dual saving mode, folders, and perform regular updates. External hard discs, cloud storage, flash sticks, CDs, email dedicated for research are the mostly used additional storage media while CDs is the most preferred. Flash sticks, CDs, external hard drives, and hard copies are used as additional storage media by MAUTECH chemists. Also, data are stored in different locations and on external hard drives as a backup method.

Other backup methods of chemists are displayed on the word cloud in Figure 4.10:

Figure 4.10: Backup and Additional Storage Device of Chemists

v. Data protection

In ATBU, chemists secure their stored data using passwords, and use of lock and key on file cabinets in the office. In FUTA, although a researcher did not believe in using password or any form of security to protect data files on the computer system, other researchers agreed to the use of password and physical security using lock and key. FUTMIN chemists use passwords, PINs, coding, anti-virus, and periodic scanning of files as security measures to protect stored data and files. FUTO chemists keep record of stored files and data in office lockers, at home, with a research assistant, or in the laboratory. MAUTECH chemists also use password for stored digital files, while lock and keys are used for physical data files as a means of securing them from unauthorised access.

vi. Hardware or software failure

Hardware and software failures are a common experience for all chemists. For ATBU chemists, such failure is usually in the form of inability to access a previously saved file after a long time or a complete system crash. Files were sometimes recovered from other researchers that they shared such files with before the crash or from the cloud storage. In FUTA, their experience is not different from the experiences shared by chemists in other FUTs in Nigeria.However, FUTA chemists usually contact the university's ITS unit for help with data recovery from their computer systems. Software compatibility issues are experienced by most chemists in FUTMIN which usually leads to loss of data. The way out as shared by the chemists is to contact colleagues for help, update software, perform system scan, or go to computer experts for data recovery. Some chemists revealed that they simply let go of such files that are unreadable or try to get from another source. Majority of chemists in FUTO has experienced hardware or software failures and inability to access old files. They describe the situation as frustrating and confusing.

> *"There was a time I was using materials studio it just did not want to come up*
> *so I had to format and lost everything"*

To regain loss data, chemists had to either consult a computer specialist, update the software, repeat experiment, perform system restore, copy from external storage device, or let go of the loss data. All MAUTECH chemists have experienced a hardware or software failure and inability to access old files which led to complete loss of data, and suffering in trying to get another data. This they say has taught them the importance of proper backup to avert future data loss. They however requested for advice and guidance on proper data storage and back up.

vii. Need for professional advice and guidance on data storage and backup

Chemists in FUTs in Nigeria unanimously agreed that they were willing to adhere to advice and guidance on data storage and backup.

Section 3 – Data sharing

This section reveals perception of chemists on data sharing and transfer of ownership of data. Figure 4.11 shows the subthemes under data sharing:

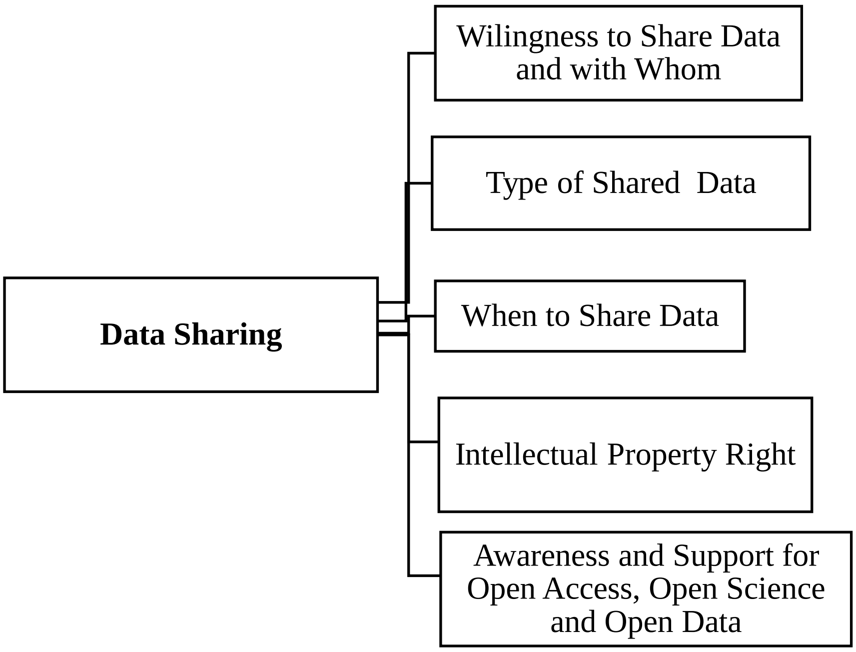


Figure 4.11 Perception of Chemists on Data Sharing

i. Willingness to share data with another user

On the willingness to share research data, there are mixed reactions as deduced from researchers' responses. Some researchers are of the opinion that once an article is published, research data is also shared automatically. This assumption is not true for most articles, as published articles are usually not sufficient to replicate a study or verify its findings. There is the need for giving appropriate access to underlying data of an article either by means of special request to the author or simply through open data repositories. However, majority of chemists in ATBU agreed to only share data after the article has been published; and it is only a part of the data and not the entire dataset.

> *"If you pick up my publication you will see my data"*
> *"Inside the publication you find the data, but you talk about the raw data that you generate from the lab? No! it has to pass through some process"*

Chemists in FUTA would share data with their research students and fellow researchers. They will also collaborate internationally and share research data but based on clearly specified terms and conditions. They are however willing to share raw or analysed research data only after publication of their findings. Majority of FUTMIN chemists are willing to share research data. Others will only share data from a research that is not sponsored and with fellow researchers home and abroad. However, there are some researchers that are simply not willing to share their research data. Those that are willing to share opined that they would only share analysed data and not the raw data. Research data sharing would occur only after publication while other researchers are willing to share before publication of final article. Only one researcher opined that data sharing will depend on the terms of collaboration. When asked whether they would be willing to share research data and with who, chemists in FUTO are of different opinions. Majority agreed to share research data but only after publication, or if the person is working on the same research, or the researcher is within the department, or a student within the university, and depends on the type of person. The other chemists did not agree to sharing research data. Chemists in MAUTECH were willing to share research data depending on the nature of the data, although one chemist felt indifferent about data sharing. However, they noted that data to be shared should be the analysed data and not the raw.

Chemists are willing to share data with fellow researchers both local and international, research students, professional bodies and funders provided the appropriate intellectual property law will be put in place. This position is in line with the observations of Carroll (2015) on the study on research data sharing and intellectual property law.

ii. Type of shared data

Data to be shared could be raw or analysed data. Most chemists were sceptical about sharing of raw data as they were more comfortable with sharing processed or analysed data. This is depicted in Figure 4.12:

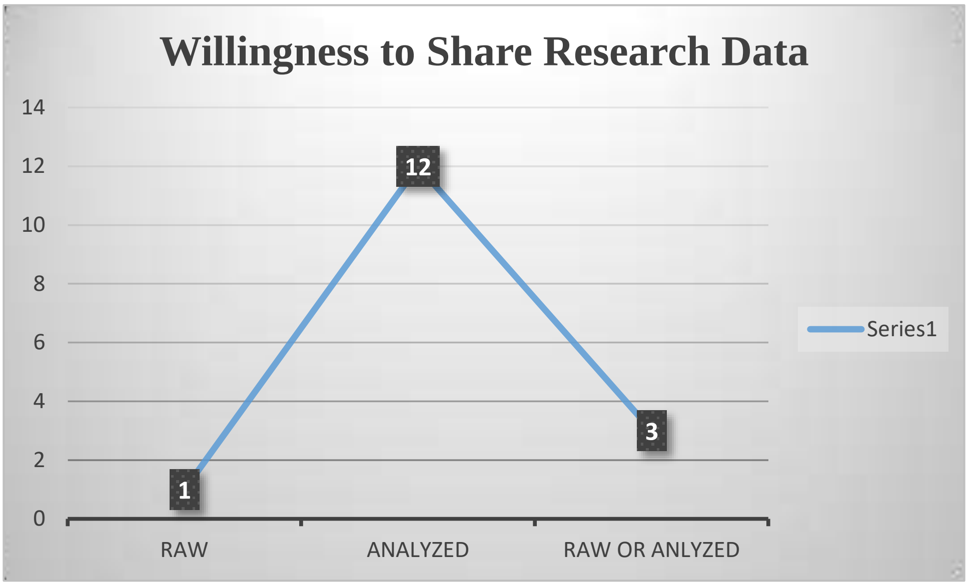


Figure 4.12: Perception of Chemists on Type of Data to Share

iii. When to share research data

Research data can either be shared before or after the publication of the research work. Chemists were interviewed on whether they would prefer to share their data before or after publication of their research work. Figure 4.13 shows their preference:

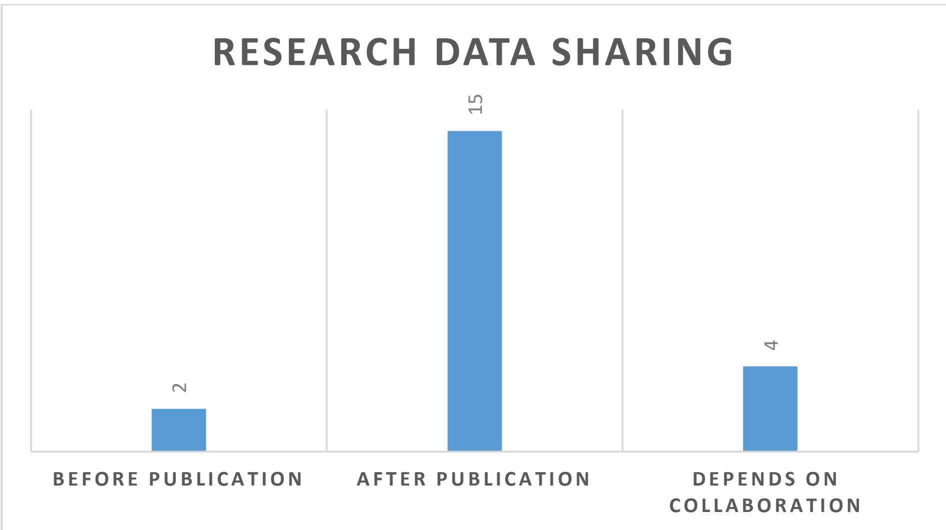


Figure 4.13 Perception of Chemists on When to Share Research Data

iv. Awareness and support for open access, open science, and open data

Chemists in ATBU Bauchi were aware directly or indirectly of the principles of open access, open data and open science, they however did not support them in entirety because of the issues of trust and attitude of fellow researchers in Nigeria. Majority of chemists in FUTA were aware of open access but only few were aware of open data and open science. They however agreed to the principles of open access to published articles only and were not in support of open data. In FUTMIN, some of the chemists have heard about open access and not open data nor open science while others have never heard of any of the open principles.

Majority of chemists in FUTO were aware of the three principles of open data, open science and open access. Only one researcher was not aware of any of the principles. All chemists have heard of open access, open data and open science and they supported all the open principles except one chemist that disagreed with the principles.

Majority of chemists were aware of at least one of open access, open science or open data. Open access, however, is the most popular among chemists as seen in Figure 4.14, and respondents were in support of these principles with few exceptions.

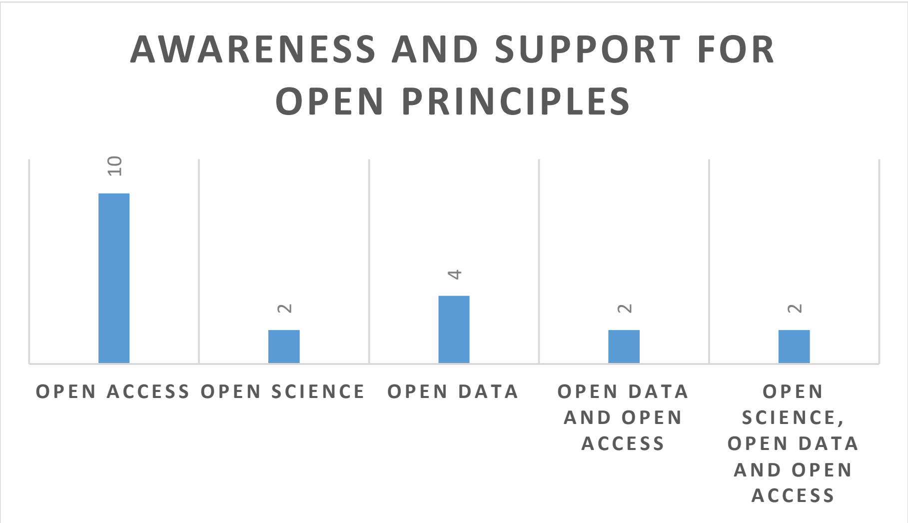


Figure 4.14: Awareness of Open Principles by Chemists

iv. Intellectual property rights

Chemists in ATBU, Bauchi and FUTA were all aware of intellectual property rights although most of them were not aware that intellectual property rights also cover research data. Few FUTMIN chemists were aware of intellectual property rights associated with research data, but majority of the researchers were not aware of such rights. FUTO chemists that are aware of open access support the principle but will only participate provided there are regulations and appropriate intellectual property rights. MAUTECH chemists are aware of intellectual property rights but have no idea of research data rights.

Majority of chemists were aware of intellectual property rights; however, a handful was unaware of intellectual rights associated with research data. In addition to this, chemists highlighted that due to their ignorance, their intellectual rights were sometimes deliberately exploited. Figure 4.15 depicts this further.

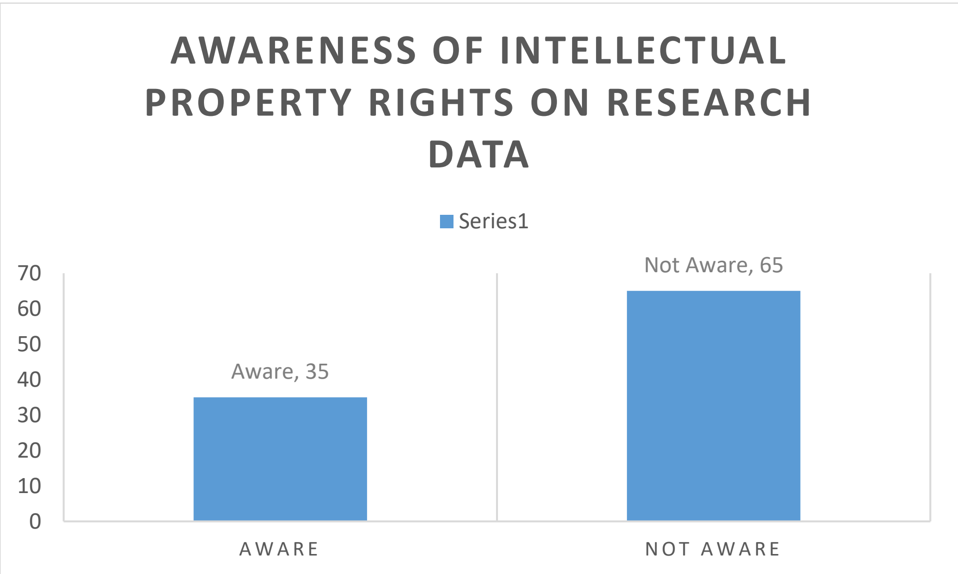


Figure 4.15 Awareness of Intellectual Property Rights by Chemists

Section 4 – Data preservation

This section presents perception of chemists on data preservation and reuse. The thematic diagram is shown in Figure 4.16:

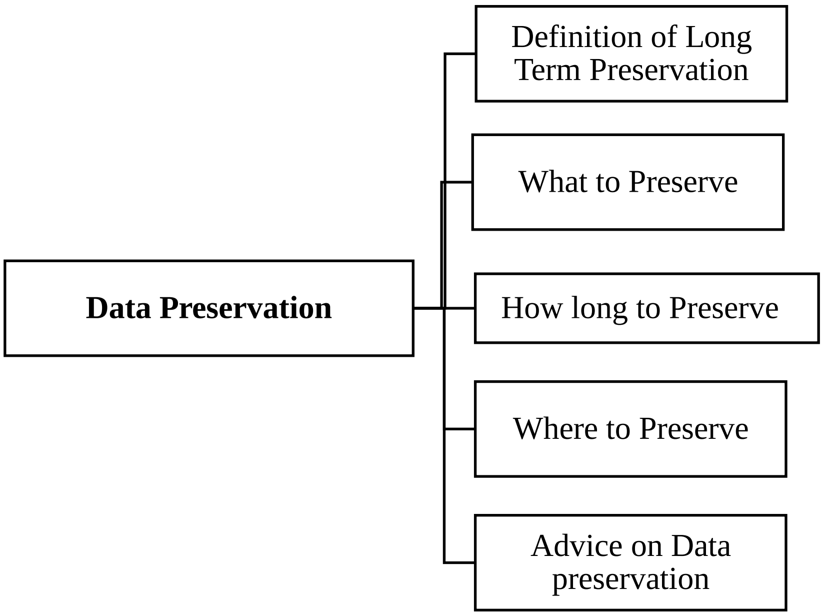


Figure 4.16: Thematic diagram of Perception of Data Preservation of Chemists

i. Definition of long term preservation

In trying to define and explain what it means to preserve research data for long term, there was no clear answer amongst chemists in FUTs in Nigeria. While chemists in ATBU and FUTA want their research data to be preserved for as long as possible, FUTMIN chemists want their research data to be preserved for a very long time, ranging from two years till infinity depending on the data type and especially if it is a sponsored research. However, some researchers want only an aspect of their data to be preserved while others want the entire data to be preserved. Chemists in FUTO want their research data to be preserved as long as it is useful and possibly for a lifetime. Chemists in MAUTECH want all their research data to be preserved for a long time, possibly forever.

ii. What to preserve

Chemists in ATBU want only some aspects of their research data to be preserved for as long as possible. FUTA chemists want all their data preserved. In FUTMIN, some researchers want only an aspect of their data to be preserved while others want the entire data to be preserved. Majority of FUTO chemists want the whole raw data to be preserved while others prefer only a part of data that is found useful. According to a researcher, preserving raw data allows for reanalysis of the data in future. While some chemists in MAUTECH want the whole data to be preserved, others want only research results and processed data to be preserved.

iii. How long to preserve

All chemists in FUTs in Nigeria stated that their research data should be preserved for as long as possible.

iv. Where to preserve

Chemists were interviewed on where they would like their data to be preserved and where to seek for help on research data long term preservation issues. ATBU chemists believed that it should be the responsibility of the university library, ITS Unit, and personal preservation efforts. Some chemists in FUTA want the library and ITS unit to be responsible for this long-term preservation while other chemists would prefer to use cloud storage services for preservation or adopt personal preservation e.g. locking hard copies of data files in an iron box or cabinet. FUTMIN chemists would want the library, copyright organisation, ITS unit, bank, cloud storage, regulatory body offices as places for their research data to be stored and preserved for long term. Only one researcher opined that no place is safe for data preservation.

Majority of the chemists in FUTO said the library is the place that should be responsible for long term preservation of data, while others opined that it should be the ITS unit, copyright offices or departmental library. However, a chemist from FUTO observed that:

"…anyway, most of my data I preserve it myself"

Another chemistalso opined that:

"I will also want my work to be preserved in the library so that somebody in future can look at my work andsee if am wrong or can build his own work".

Preservation, according to MAUTECH chemists, should be done either personally, on the internet using email, by the ITS unit, or library. Figure 4.17 shows a word cloud on where chemists would prefer to preserve their data for long term:

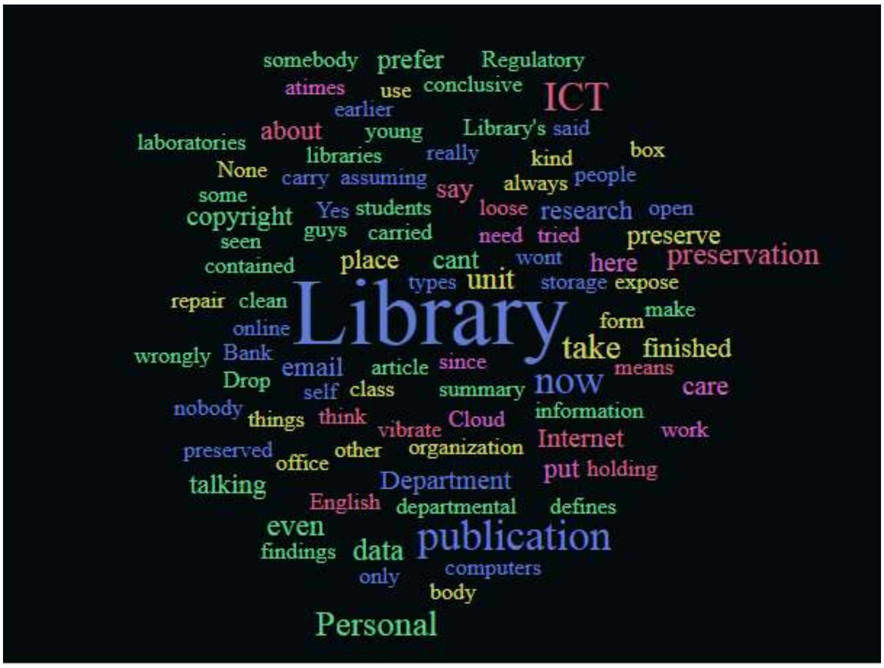


Figure 4.17 Perception of Chemists on Where to Preserve Data

Library, as the preferred place for data preservation is also supported by Flores *et al.* (2015) study who opined that "the library is well situated to be a key player in data management, curation, and preservation, given its extensive experience with selection, metadata, collections, institutional repositories, preservation, curation and access".

v. Acceptance of advice or guidance on research data preservation or reuse

Majority of the chemists stated their willingness to accept available advice or guidance that would improve their research data preservation and reuse skills. However, a chemistsaid that self-preservation is adequate for research. This opinion was also observed by Kuula and Borg (2008) who noted that research data collected remain in the hands of original researchers without any long-term preservation plan.

Section 5 – Data management plan

This section presents chemists' perceptions on data management plan and policies that may influence data management practice. Figure 4.18 shows the subthemes:

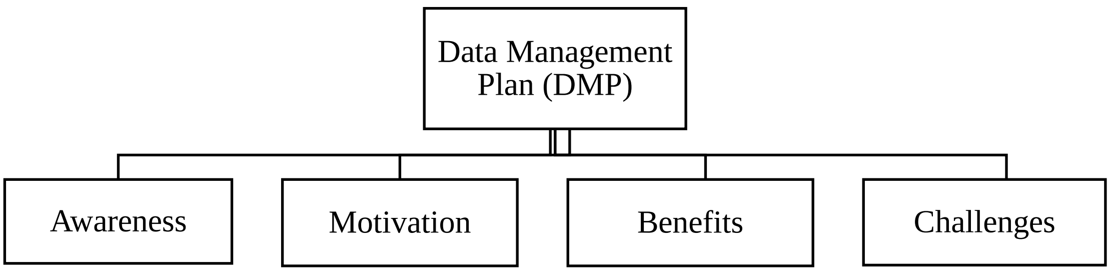


Figure 4.18: Perception of Chemists on Data Management Plan (DMP)

i. Awareness

Surprisingly, very few chemists in FUT in Nigeria were aware of a data management plan and as such, they were unable to give a concrete definition of DMP. None of the chemists in ATBU was aware of a data management plan. They were however willing to learn and be guided on how to manage their data for long-term preservation and reuse. None of FUTA chemists was aware of a data management plan; however, they saw it as a good research practice that should be adopted by all researchers across disciplines. They also require awareness and enlightenment on the need for data management plan, data safety, as well as global best practises on data management practices. None of the researchers in FUTMIN has heard about a data management plan (DMP). However, researchers indicated their interest in how to store, preserve and secure research data. They also need guidance on how to use the repository and any other awareness and available guidance, preferably a computer-based research data management. Chemists in MAUTECH were not aware of a DMP. They were however, willing and ready to learn and adopt any available and relevant research data management system, especially a computer-based data management system.Here, a chemist shared a story thus:

> *"I know of a case, international case, where a Nigerian did a work and somebody took the work. When theNigerian saw it, he complained to the body and it was an international case. It was resolved when they askthose guys that claimed the result to bring the evidence of the raw data so it was the raw data that vindicatedthe Nigerian who has been keeping record…".*

Few chemists in FUTO were aware of a data management plan (DMP). Requirement from funders, writing a paper for impact factor journals like *Nature* and *American Chemical Society*, and avoiding excessive spending are some of the motivations for writing a DMP. These chemists believed that a DMP makes research easier, helps to monitor online visits, saves costs, eliminates boredom and fatigue and overall, makes life easier. However, challenges encountered with a DMP are that it allows for pre-emptive data, narrows the scope of work, and difficulty in complying with different disciplines and funders requirements. This situation was in line with VanTuyl and Michalek (2015) and Sewerin *et al.*(2014) study where it was observed that there is the need for harmonization of funding requirements by funding agencies as regards data management plan. The study concluded that there is the need for librarians to help researchers on data management so as to save time in other aspects of data management and sharing.

ii. Motivation

Some of the reasons that could motivate chemists to prepare a DMP are:

- need for a detailed record of research processes;
- the need for protecting intellectual properties;
- requirement from funders and impact factor publishers;
- preparing an article for journals like Nature, American Chemical Society;
- to avoid excessive spending;
- good research practice.

iii. Benefits

Benefits of DMP as shared by chemists are:

- *"If the data are well managed, after some time, they can be used for further analysis or a completely new research*";
- helps to make research easier;
- encourages sharing and preservation;
- *"Ease research life in future, if well managed".*

iv. Challenges

Challenges of DMP as mentioned by chemists include:

- awareness;
- allows for pre-emptive data and narrow the scope of the work;
- *"I don't know how to use it but I can learn if it is developed";*
- makes data management easier;
- *"Problem of meeting with different disciplines' requirements"*.

Section 6 – Perception of chemists on research data management

This section presents chemists' perception of research data management practices. The subthemes are shown in Figure 4.19:

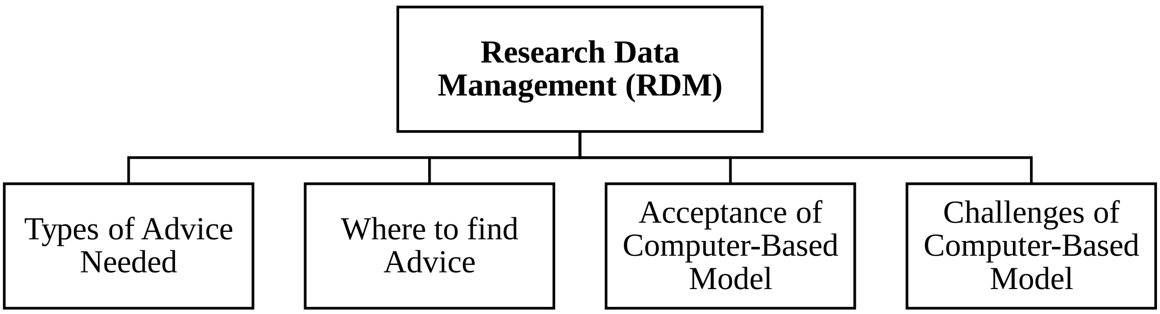


Figure 4.19: Perception of Chemists on Research Data Management

i. Types of advice needed

Chemists in all FUTs in Nigeria require advice and/or guidance in the following areas:

- more enlightenment on the need for Data Management Plan (DMP);
- data safety;
- advanced programme to help with data management;
- storage, preservation, security of data;

- available on research data management;
- funding;
- repository.

This is depicted further in the word cloud of Figure 4.20:

Figure 4.20: Advice Needed by Chemists on RDM

ii. Where to find advice

Chemists in FUTs in Nigeria believe the best place to find help or seek guidance in research data management is the library. Libraries offering RDM services can have a great impact on theircommunities by supporting communication among researchers, enhancing knowledge of the data life cycle, providing disciplinary and institutional resources, and emphasising the importance of documentation of data sharing (McLure *et al*., 2014). Other places include ITS department, and within the institution.

iii.Acceptance of computer-based data management model

Majority of the chemists in FUTs in Nigeria are willing to accept a computer-based data management model. Although some chemists believe they can comfortably handle the data themselves through personal management and preservation efforts, others are willing to accept a computer-based data management model "*if it is secured*".

iv. Challenges of computer-based data management model

Chemists in FUTs in Nigeria gave the following as their perceived challenges to a computer-based data management model:

- software limitations;
- "t*oo much stress for me*";
- leakage of data and data security;
- virus attack;
- "*it might be general with no regard to specific options in chemistry*";
- system crash and data loss;
- erratic power supply;
- compatibility issues, availability, and accessibility.

Figure 4.21 presents this issue in a word cloud and shows 'security' as the greatest challenge to RDM as perceived by chemists in FUTs in Nigeria.

Figure 4.21: Perceived Challenges of a Computer-Based Data Management Model

From the foregoing, the perception of chemists on research data management has been explored thoroughly with the above qualitative data analysis. This implies that the first objective of this study, which was to determine the data management practice of chemists in FUTs in Nigeria, has been achieved.

However, to be able to develop a successful research data management model, there are three units in the university whose awareness and support system would go a long way in helping researchers develop an optimised and thorough data management model. These units are: Library, ITS Unit, and Research Unit. The responses from these stakeholders, who are the head of each unit, was analysed with the aim of identifying the awareness and expected support systems for a successful research data management in their respective universities.

4.4 University libraries

In determining the awareness and support systems expected from the library for effective research data management, university librarians of all federal universities of technology in Nigeria were interviewed and the following represent their responses:

FUTMIN, ATBU, FUTA, and FUTO all have an institutional repository except MAUTECH that are really working to deploy theirs soon.

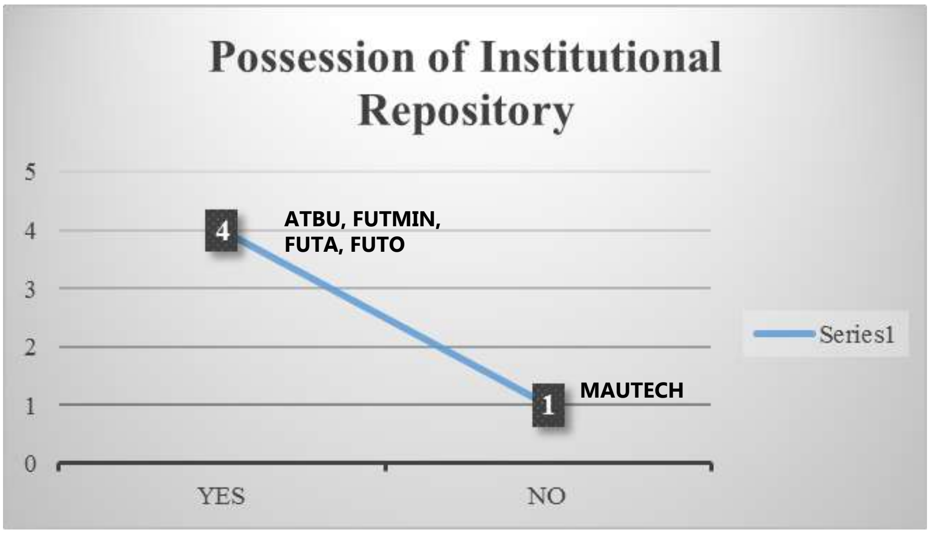


Figure 4.22 Possession of Institutional Repositories in Libraries of FUTs in Nigeria

FUTA has a dedicated digital repository where research data are kept while ATBU is still working on creating a database for research data. Other university libraries are yet to record any research data submission. This is shown in Figure 4.23:

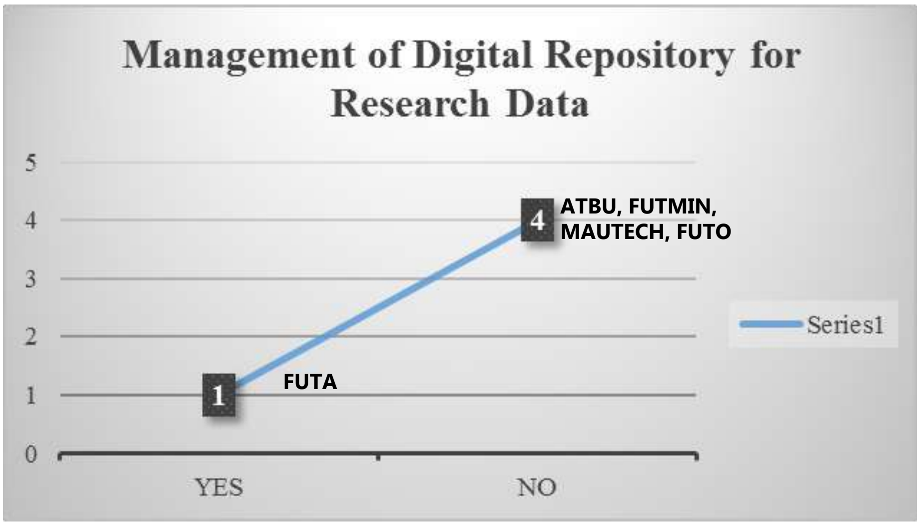


Figure 4.23 Management of Digital Repositories for Research Data

ATBU, FUTA and FUTO libraries are aware of research data management. The awareness was either through an international conference they attended or read through journal articles. Libraries that already have repositories have better support systems available for successful research data services.Availability of an IR is an indicator that shows that the skill sets, longevity, and most of the infrastructure needed to accomplish RDM task are available (Heidorn, 2011).

Research Data Management (RDM) services are being implemented by academic and research libraries globally in support of university research activities. According to Chiware and Mathe (2015):

> "in South Africa, some libraries are beginning to provide frameworks for these services with some degree of success as policies are being formulated, infrastructure set up, library staff trained, and awareness and advocacy campaigns held with academic staff and researchers".

Furthermore, Rice & Haywood (2011) presented the research data management initiatives at the University of Edinburgh, United Kingdom, to include adoption of university policy that sets out rules for the retention of and access to data related to research publications as well as the obligations of institutions to provide support for doing so. Heads of libraries that are aware of RDM are shown in Figure 4.1.23.

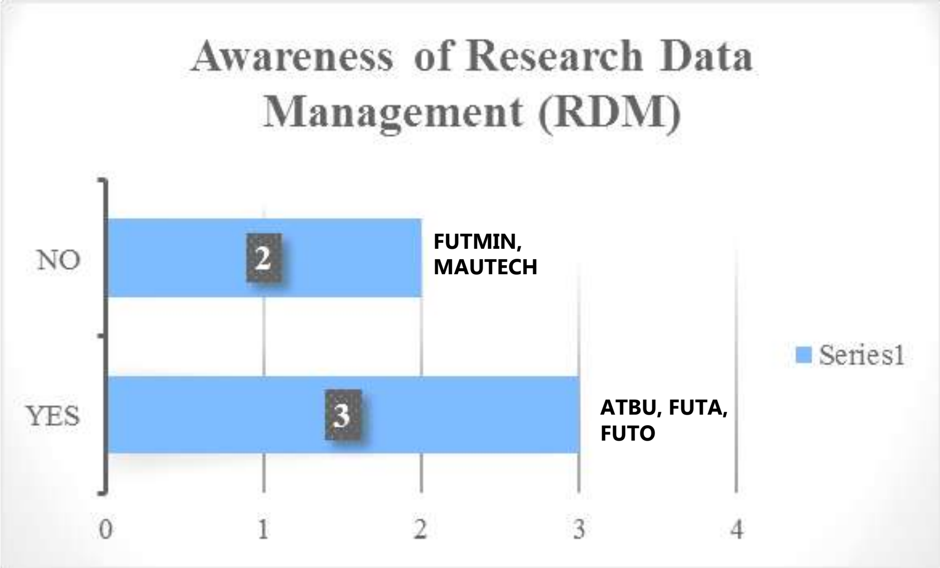


Figure 4.24 Awareness of RDM

Only FUTA and MAUTECH have research data submitted to the library or on the institutional repository (IR) as shown in Figure 4.25:

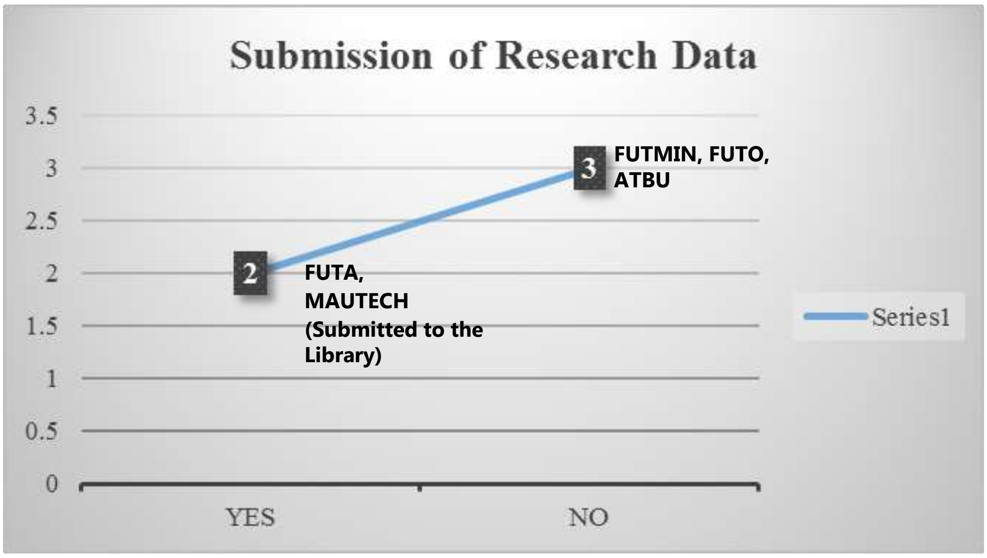


Figure 4.25 Submission of Research Data to Library or IR

On the issue of access to continuous professional development of librarians' skills to cope with emerging trends in research data management and sharing, most university libraries specifically ATBU, FUTA, FUTO and FUTMIN encourage this and such developmental programmes were organised both internally and externally and funded either by Tertiary Education Trust Fund (TETFund) or through international funding agencies that support Continuous Professional Development (CPD) programmes. They however noted that such training programmes might not specifically be on research data management.

On librarians' ability to provide access to research data by means of standard metadata generation, librarians in FUTMIN, FUTO have the required skills; some of the librarians in FUTA; and none in ATBU and MAUTECH. ATBU noted further that,

> *"presently, we do not have that skill, but we can provide access to all the resources on our database currently, but in terms of metadata data management, No. Librarians do not have enough skill in that area."*

Chiware & Mathe (2015) equally suggested the need for further skills development for librarians as they strive to support research data services, and awareness and advocacy campaigns to be held with academic staff and researchers.

All university librarians are familiar with open access, while some are familiar with open data. None of the libraries are aware of open science. All the libraries have access to several open access repositories which cuts across all disciplines but none for open data repositories.

MAUTECH and FUTMIN are yet to have Intellectual Property Rights policy guiding the use of their institutional repository while other universities have one guiding them. This is depicted in Figure 4.26:

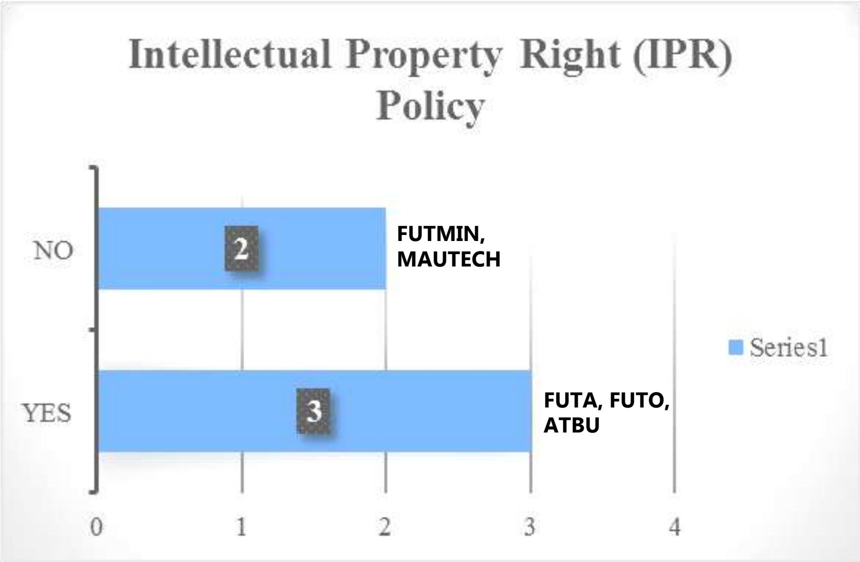


Figure 4.26 Libraries having IPR Policy

All university libraries provide advocacy to researchers on the importance of submitting research data and related publications to the institutional repositories and noted furtherthat researchers are not complying well with uploading submissions to the institutional repository.

Poor attitude of researchers towards submission of research data and other intellectual output to the library is seen as a possible challenge to research data management. Librarians noted that researchers' exposure to research best practice positively affect their attitude towards research data management and related publications. It was also noted that periodic awareness as well as listing total number of publications deposited by each researcher on the repository will encourage others to upload theirs too on the institutional repository.

All libraries in FUTs in Nigeria agreed that librarians will require additional training on metadata generation from research data and this can be done through organising workshops and seminars on research data management for both librarians and researchers.

Finally, whatever solution is deployed should be adequately funded to help in meeting its objectives. Provision of facilities which includes current and up-to-date software and hardware, continuous training and retraining on benefits of open access and open data and uploading on institutional repository, consideration of staff welfare, synergy between the library and ITS unit and repositioning the library as a Hub within the university will all help to achieve an effective research data management in the universities.

4.5 Information Technology Service Units

The Information Technology Service (ITS) (also known as ICT) units of FUTs in Nigeria is a service-oriented unit that has a generic function of providing Internet services, provision of wired and wireless network solutions, repair and maintenance of computer facilities, training staff and students on the use of computer and associated technologies as well as supporting computer-based examinations and tests. They are also in charge of the universities' Management Information System (MIS) which encompasses students' online registration, course registration, allocation of students hostels, checking of result, uploading staff profile and a host of other services as directed by the university management.

ITS units also offer support to researchers through sensitisation on available open source materials, electronic resources, local contents, databases, computers and software for research purposes, free Internet access, development of researchers' ICT skills, provision of bandwidth for data-driven researches, managing the institutional repositories, provision of software defined networking such as classroom simulations, open source journal development, assist in setting electronic library, and ensures internet access in every faculty and department. Moreover, the ITS unit supports the university library in installation, configuration and management of the institutional repository (IR).

In FUTO, there is a dedicated ITS unit within the library building specifically meant for deploying library services like the open educational resources. The relationship between the ITS unit and library is said to be cordial and smooth in all the FUTs in Nigeria. The ITS unit collaborates with the library in the areas of Internet connectivity, installation and software configurations, computer maintenance and management, accessibility to institutional repository through wired or wireless access, facilitate collaboration with international electronic databases such as EBSCOHost, and hosting and management of library management systems e.g. KOHA as well as repository managers e.g. DSpace, E-Prints; and departmental e-libraries.

In ATBU, ITS unit is helping the library in setting up a data centre with complete Internet protocol IP address so they can host and manage their electronic resources and repository locally.

The institutional repository of FUTO is managed by the library; MAUTECH's repository is managed by ITS unit and the library; FUTA's repository is managed by the ITS unit and hosted on the university's website; FUTMIN repository is managed by the ITS unit although it has currently expired; ATBU repository is on-going and almost completed.

When asked if the ITS unit has adequate storage space for research data, all the ITS units of FUTs in Nigeria said they have enough storage space for research data. However, FUTA ITS unit had an unfortunate fire incidence but plans are already on the way to develop a data centre offshore. FUTMIN also noted that storage space is relative as there is enough space for now but in the long term, there would be need for upgrade to accommodate the growing intellectual output emanating from the university. This opinion is also shared by the ITS unit of ATBU.

The safety and security of research data stored on the repository is of utmost concern to all researchers. ITS units will ensure this by deploying adequate physical security measures, use of firewalls and anti-virus, encouraging sharing of data among researchers as a way of backing up their research data, and regular update of software and programmes. The units also noted repository manager like DSpace comes with a lot of security features and patches that makes it less vulnerable to security threats. However, hacking of servers and programmes still pose a great threat to most of the ITS units in FUTs in Nigeria.

The following are challenges to effective research data management as stated by ITS units in FUTs in Nigeria:

- lack of continuous upgrade of software and programs which are usually capital intensive;
- trust issues on the part of some researchers to come forth with their research data and other intellectual output;
- poor turnout at workshops and trainings on using the repository;
- inadequate human resources on various critical areas of ICT;
- corrupt data submitted by researchers or uploaded on the repository;
- lack of power backup and erratic power supply;
- poor or out-dated infrastructure and inadequate storage space;
- poor data management skills.

The ITS units however noted that for a successful implementation of research data management in the university, the following must be considered:

- special provisions for equipment procurement by university management;
- establishment of a standard data centre for RDM with full power backup and up-to-date software and programs;
- capacity building for ITS staff;
- user education to build researcher's trust in the system;
- more funding and commitment from the university management.

4.6 Research and Development Units

The Research and Development (R&D) units of FUTs in Nigeria are responsible for ensuring research best practices in the universities under study. The unit advises the university management on research related matters, helps create collaboration and partnership between researchers and grants donors, educate researchers on research methodologies and assists them in writing grant winning proposals and write-ups. This unit has been deploying various services and programme to facilitate research in the host university. In ATBU, there is the Research Innovation, Collaboration, and Technology Park aimed at bringing research findings in to life i.e. an incubation center. Research best practices, according to the units, involve understanding what the research problem is all about and ensuring that every research is problem- and user-driven. Effective data management is also considered research best practice. Judiciously using fund allocated to research to achieve the aim is another best practice.

There are several research grants both local and international that chemists have been winning. Example of such grants are Senate research grant, university research grant, Tertiary Education Fund (TETFund) research grant, National Communication Commission grant, grants from private agencies, STEP B- European Union, International Foundation of Science, IDRC Canada, World Academy of Science, German Agencies like WASCAL and so on. Chemists in FUTs have been winning such grants with the highest number of researchers winning local grants than international grants. TETFund research grant is the highest won research grants in FUTs in Nigeria followed by NCC, German grants and STEP-B.

It was revealed that researchers do not have knowledge of data management plan which is part of the requirements for some of the grants. However, the unit has been deploying different services to assist researchers through workshops and seminar on grantsmanship, proposal writing, printing of booklets on research ethics and proposal development, mentorship through collaboration with local and foreign researchers and formation of research groups.

There is a research policy available that covers issues of copyright and patented discoveries between the researcher and the university. In FUTA, the intellectual property unit is responsible for management of research outputs and the unit is linked to National Office for Technology Acquisition and Promotion (NOTAP) to strengthen the policy. In MAUTECH, there is MAUTECH Research Policy and MAUTECH Research Strategic Plan (2018-2022) aimed to guide and protect research activities within the university. FUTMIN through the Directorate for Research Innovation Development (DRID) is mandated to maintain research output including research data generated locally and internationally.

Several suggestions were given for a successful implementation of research data management policy in FUTs in Nigeria. Some include: establishing a special research data management unit incorporating research information and statistic unit; awareness creation on the importance of data protection and intellectual properties; and support from university management in educating researchers and sensitizing the university community.Chemists in FUTs in Nigeria perceived data to be raw facts and figures while research data is any information gathered before, during and after an experiment or research. Chemists have an appreciable understanding of data and research data which made it easy to buttress the need for its effective management and long term preservation and reuse.

Chemists generate lots of digital data in various forms and formats. However, digital data are mostly in the form of spreadsheets and NMR spectra. The software used for the digital data generation includes: Microsoft Excel, SPSS, and machine-dependent software. Since these software are proprietary, once the developers or owners stop supporting the software, chemists would be at risk of great data loss.Most commonly used data naming system among chemists in FUTs in Nigeria include combination of name, source, and date. Using a standard data naming system ensures that data files are easily retrievable and well organised. This practice also prevents loss of data. A standard data naming convention also makes it easy to manage different versions of data files.

Chemists have experienced several unfortunate data loss due to damaged external hard disc, power failure during experiment, spoilt flash drive, corrupted files, sudden system crash and data loss during upgrading from software to the other. This has made chemists to appreciate the use of back up, saving in multiple places, and update of files.Portability, safety and capacity are the most important determinants of a storage media device. However, chemists still rely greatly on hard printed copies as additional storage device and backup.Password and PINs are the mostly used method for securing data by chemists. Chemists are willing to learn additional storage and backup methods.

Estimating research data size is quite difficult for chemists. This has a consequent effect on assignment of storage space on severs that would eventually house the generated data for long term preservation.Most chemists were willing to share analysed data after publication depending on the situation and an established agreement. Those that are not willing to share data gave trust issue as the inhibiting factor.Majority of chemists supports the open access principle while awareness of open data is still very low. Most of them are not aware of intellectual property laws that guide research data and sharing.Chemists want their research data to be preserved for as long as possible in the library.

Few chemists are aware of data management plan while applying for international funding and grants or when preparing to submit manuscript for publication in impact factor journal.From the foregoing, it is evident that chemists have had terrible and regrettable experiences of data loss, hardware and software problems, sudden system crash, poor backup systems, as well as inadequate research data management practice. There is, therefore, the willingness to use a secured computer-based data management model that would help guide and manage their research data.To solve some of the identified challenges, and having understood chemists' workflow and environment, this study seeks to develop a computer-based data management model that would fit into researchers existing workflow and help manage research data effectively. Chemists were also willing to participate in any awareness programme, training or workshop that would help improve their research best practices.

Librarians on the other hand, are aware of research data management, although their skills are not adequate especially in the generation of standard metadata from research data. However, the support systems necessary for effective research data management are available in most of the libraries of federal universities of technology in

Nigeria.Awareness, training workshops, continuous professional development programmes that would be funded for greater impacts are recommended for both librarians and researchers.The ITS units have also been collaborating with the library in deploying data centres, managing institutional repositories, ensuring safety of intellectual output stored on servers within the university, ensuring reliable internet access, managing the university's management information system, as well as supporting research in various ways.The research and development units of FUTs in Nigeria are responsible for supporting research best practices in the university. The unit also ensures that researchers are guided properly on how to apply for grants from local and international sources, proposal writing, implementing the research policy of the university, ensuring strict adherence to research ethics as well as other issues related to research and development of the university and the country at large.

4.7 Suggested actions based on findings

After a careful study of perception of chemists on data management and sharing and the available support systems from the library, ITS, and research and development units, the study recommended the following:

For Chemists:

1. the need to adhere to an established data naming convention especially in chemistry;
2. periodic and continuous update of data files saved in multiple locations;
3. improved data sharing practice which could also serve as a preservation method;

4. use of institutional repository to assist in easy discovery of research data and long term preservation.

For the Library:

1. the need for sustained advocacy and training on the use of institutional repository;
2. continuous improvement of data management skills of librarians to cope with the emerging research data services in universities;
3. improved awareness on intellectual property rights where it is available.

For ITS Unit:

1. improved security of the institutional repository to curtail the problem of cyber hacking and related threats to intellectual contents on the institutional repository;
2. a good foresight of possible increase in server storage space and in collaboration with library, convincing the university management of the need for continuous upgrade of software and programmes used by the institutional repository.

For Research and Development Unit:

1. sustained effort in improving the research best practices among researchers in the university;
2. awareness on latest requirements of international funders and impact factor journals;
3. organising workshops and trainings on writing award winning research grants and data management plans.

Research Question 2: What computer-based data management model suits existing research process of chemists in FUTs in Nigeria?

4.8 System analysis of chemists' research process

Research data are generated across the research process and workflow of chemists in FUTs in Nigeria. System analysis showed that the existing research process of chemists have areas of overlap at some point of their research. However, there are still areas of research that are distinct and specific to some options in Chemistry. Data items are generated and expected to be stored properly during and after the research. These variations and specificity were considered and the following presents a description of the existing research process and workflow of chemists in FUTs in Nigeria:

4.8.1 Organic/inorganic chemistry

Chemists in these options start their research process by identifying a problem, set an objective and an expected outcome. Then they proceed to extraction which usually includes identification and collection of extracts. For organic chemistry research, such extract may be from leaves, fruits, seeds, bark of trees and so on. They then define method of extraction and procedure for extraction. Screening, testing and validation is followed by isolation of constituents and then characterization. Constituents are validated either singly or through synergy of constituents. After the revalidation process, conclusion is made and finally, result is acquired. Figure 4.27 depicts the research process of organic/inorganic chemists as observed by the study:

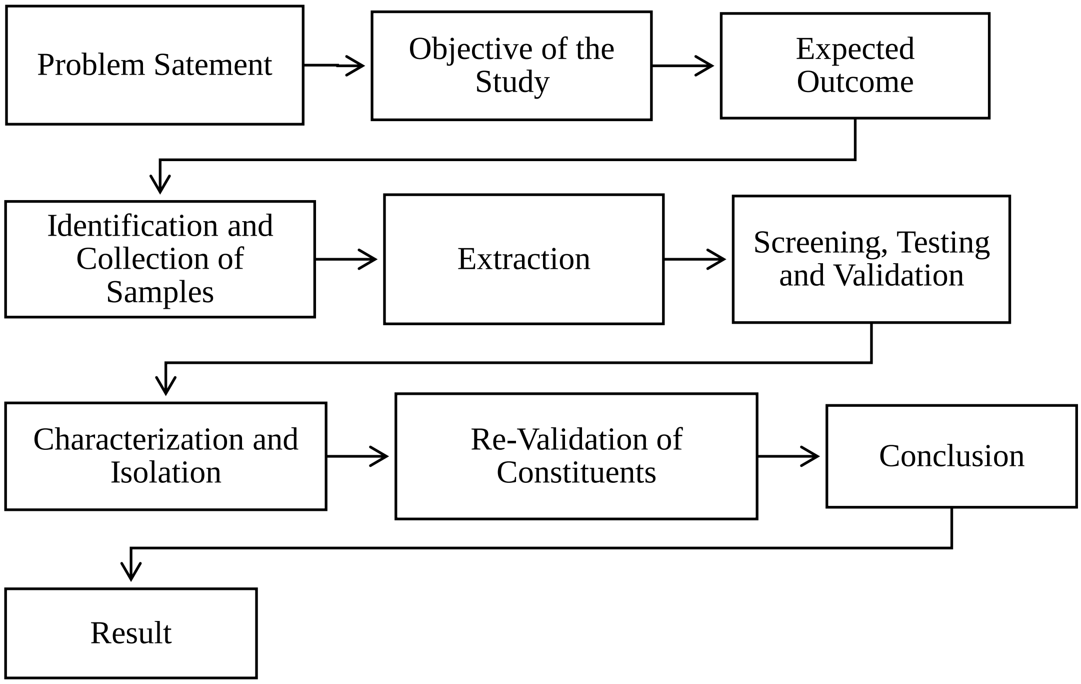


Figure 4.27: Research Process of Organic/Inorganic Chemists

4.8.2 Industrial/polymer/geochemistry/petroleum chemistry

These options deal with exploration, materials manufacturing, and industrial products. The research process starts with problem identification, setting objective and an expected outcome. Identification, mapping and collection of samples is done and collected samples are treated using selected procedures. Characterization is done using various analytical techniques like X-ray Fluorescence (XRF), quantitative X-ray Diffraction (XRD), High Resolution Scanning Electron Microscopy (HRSEM), Brunnair Emmette Teller (BET). For polymer option, method development and characterisation of composite material is done using Viscometer, Thermal Gravimetric Analysis (TGA), X-Ray Diffraction (XRD). Interpretation of results follows and the study is concluded. Figure 4.28 shows this research process:

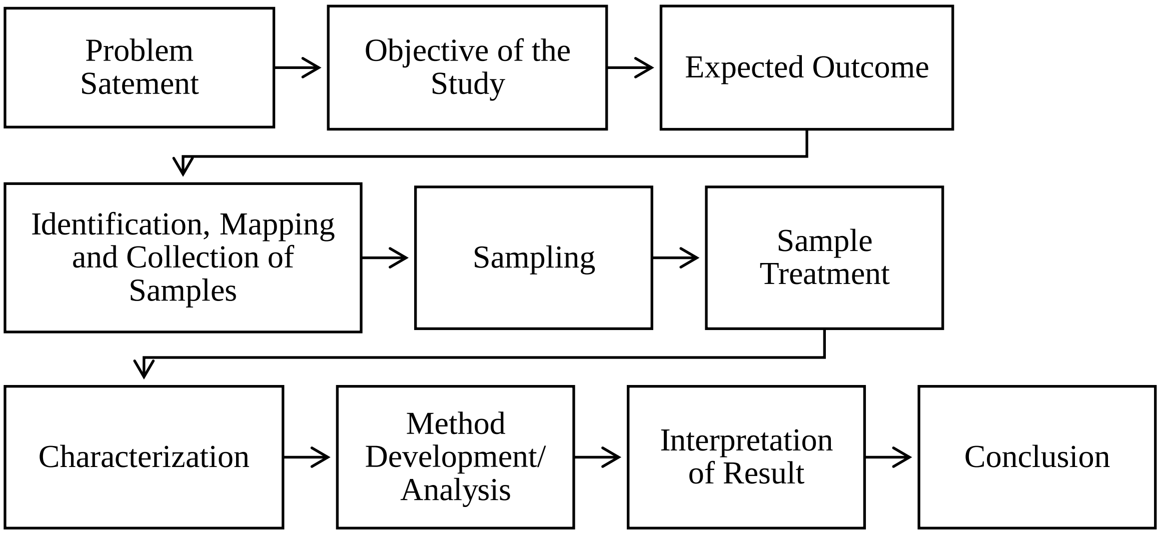


Figure 4.28: Research Process of Industrial/Polymer/Geochemistry/Petroleum Chemists

4.8.3 Analytical/food/physical chemistry

Research process is initiated with a problem identification, setting objectives and expected outcome. This is followed by identification of sampling site with regards to problems identified and the sample collection. The collected sample is subjected to pulverisation, digestion of the pulverised sample and sample analysis. If there is presence of heavy metal in the sample, the analysis will be done using Atomic Absorption Spectroscopy (AAS), or Inductive Couple Plasma-Optical Emission Spectroscopy (ICP-OES); but if the sample contains only traces of metal, flame or spectrophotometer is used. Interpretation of result is done using software of choice and the study is concluded. Figure 4.29 shows this research process:

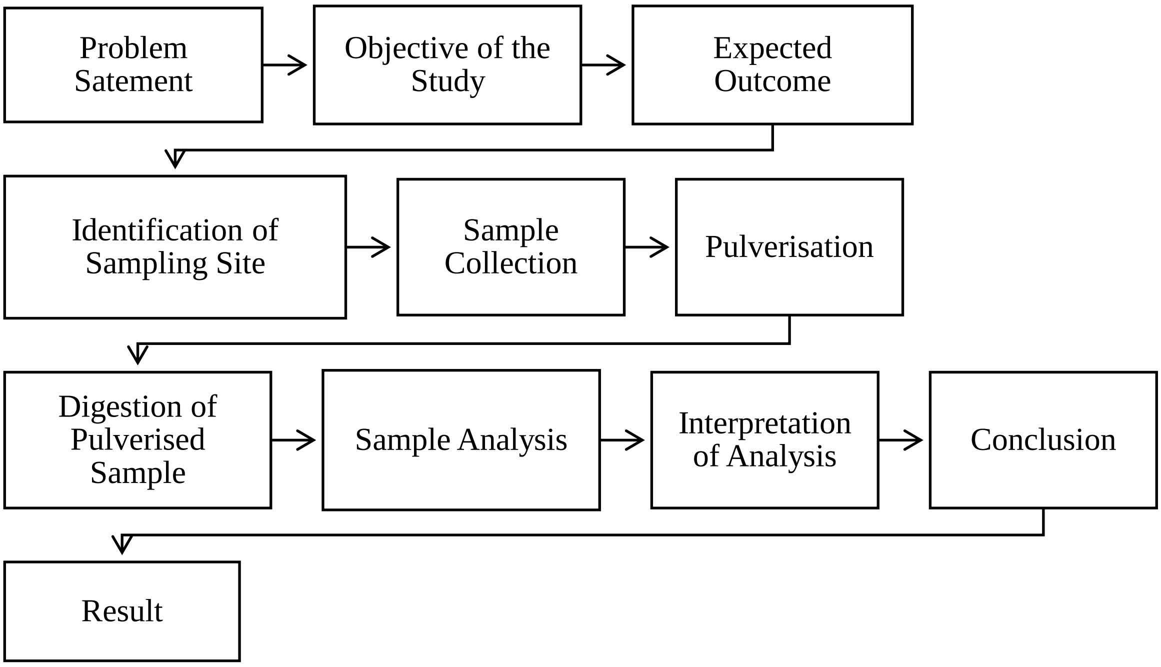


Figure 4.29: Research Process of Analytical/Food/Physical Chemists

4.8.4 Environmental chemistry

The research process is started with problem statement, setting objective and expected outcome. Then a sample site is identified for collection of samples. If the sample has an organic constituent, extraction is done using solvent, then pre-concentration, analysis of filtrate to quantify the organic matter using any of these chromatographic techniques- Gas Chromatography Mass Spectroscopy (GCMS), Liquid Chromatography Mass Spectroscopy (LCMS), High Performance Liquid Chromatography (HPLC). Calibration is done using known standard. Retention time is noted for each calibration done. Then the study is concluded and result presented. Figure 4.30 shows this research process:

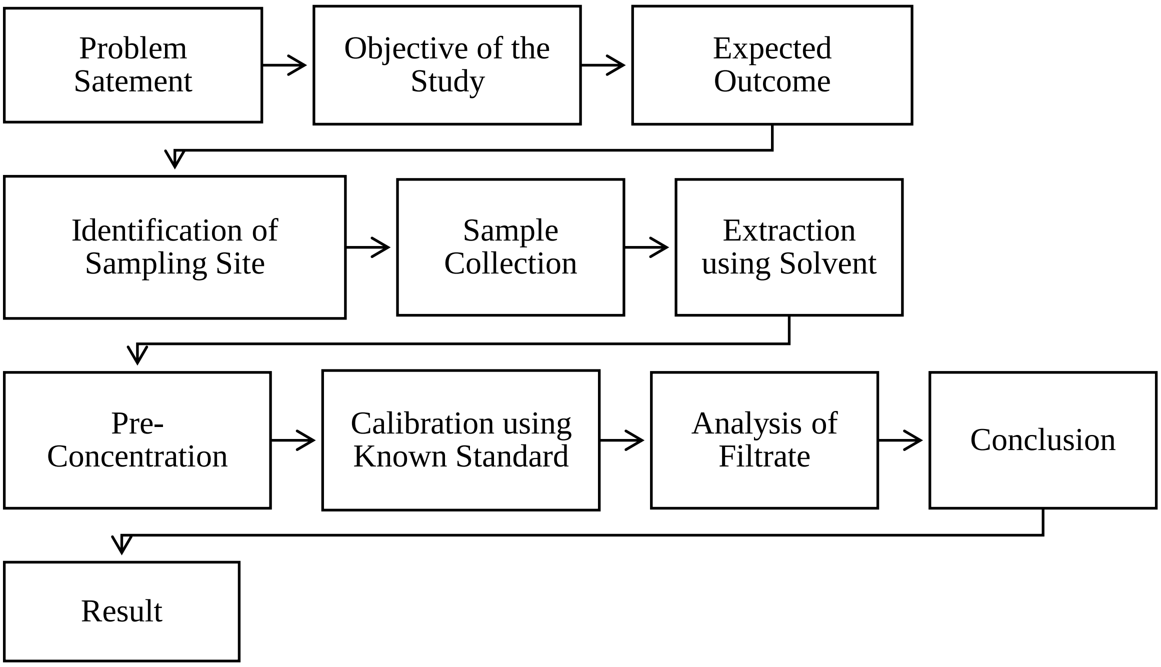


Figure 4.30: Research Process of Environmental Chemists

4.8.5 Nano-chemistry

Nanochemists start their research process with problem identification, setting an objective and determining the expected outcome. After a problem has been identified, synthesis of nanomaterials follows. Synthesis could be done using: the green method, hydrothermal method, solvothermal method, photo reduction, electrodeposition, photo deposition. Then characterisation follows using any of the analytical techniques like the X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), and Transmission Electron Microscopy (TEM). The result is interpreted and the study is concluded. Figure 4.31 depicts this research process.

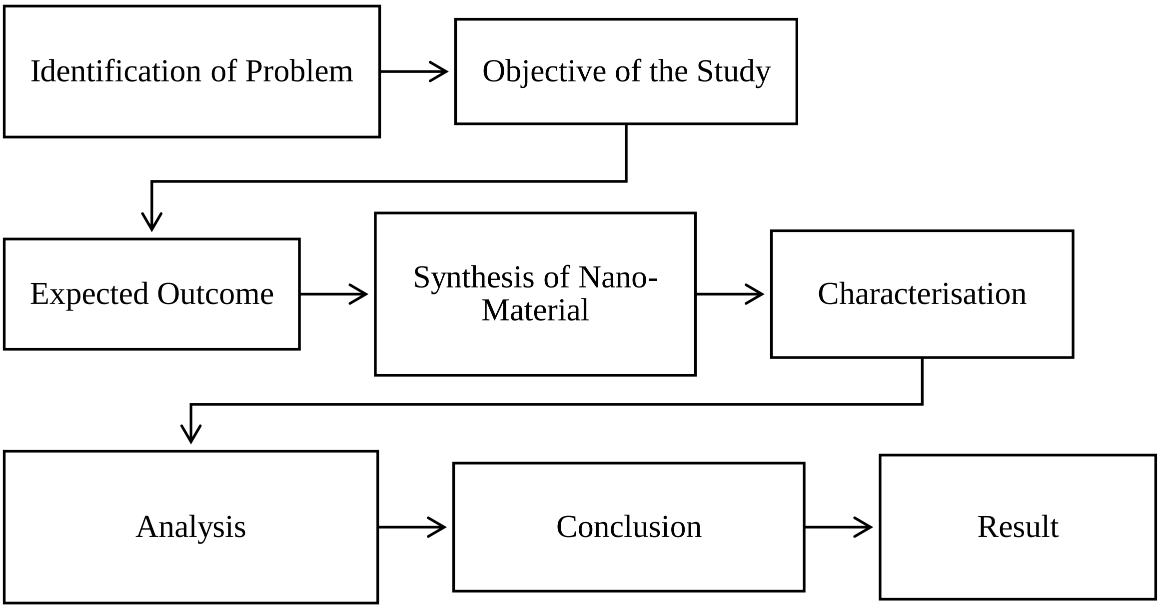


Figure 4.31: Research Process of Nano-Chemists

4.8.6 Computational chemistry

Computational chemistry starts with problem formulation involves extensive use of

software simulations and interpretation of results as shown in Figure 4.32:

Figure 4.32: Research Process of Computational Chemists

It is worth mentioning that research process in chemistry is often started with a problem statement, an objective and an expected outcome. These expected outcomes are sometimes stated as hypotheses to be tested with an experiment. Their research methodology differs across options although there are areas of overlap among them. Software is used for research design and interpretation of result and concluded research are usually disseminated through publications, conferences, commercialised or patented.

The limitations of the existing system are:

i. chemists are not aware of those research data items that must be stored and kept throughout their research lifecycle for future reuse. They also do not observe appropriate research data management practice thereby making it difficult to have a complete, verifiable, sharable datasets at the end of the research;

ii. most chemists keep records of research data in a laboratory notebook in which data items are not properly defined or described. These laboratory notebooks are also prone to theft, loss, or even deterioration after a long time.

It is only a well-kept research dataset that could be submitted to the library for long term preservation and reuse, hence the need for a system that will guide and assist chemists to willingly manage and curate their research data and then, send it to the library for permanent preservation.

4.9 The Proposed Research Data Management System

Research data are generated right from the beginning of the research process to the end when the study is finally concluded. Specific data elements are also generated and stored at each of the research stage and process. A data element is an attribute of a data entity. In a research, data elements help to hold value or meaning of an activity conducted during the research process. An example of a data element include author, title, funder, and sample. The computer-based data management that the study seeks to develop will use this workflow and processes to produce a software prototype that will fit into chemists' workflow.

Figure 4.33 below shows the generic research process of chemists in FUTs in Nigeria:

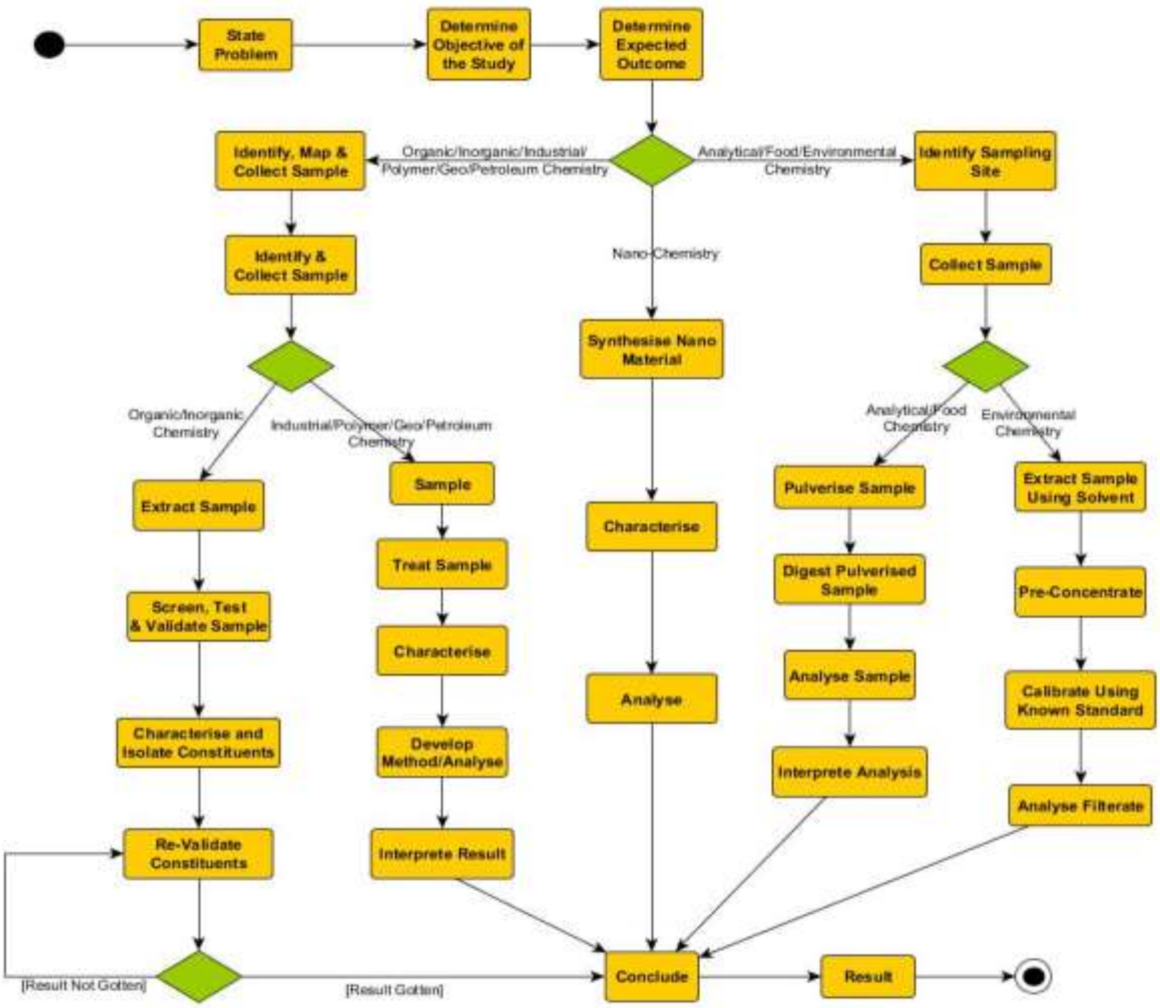


Figure 4.33: The Generic Research Process of Chemists

4.10 System testing and implementation

Black box testing was used to test the system and to ensure that all the components work together with no error. Black box testing is a software testing method in which the internal structure/design/implementation is not known to the tester. It is usually conducted to ascertain users' acceptance testing of an information system. This method attempts to find errors in the following categories: incorrect or missing functions, errors in data structures or external database access, behaviour or performance errors, initialization and termination errors.

The Chemistry Research Data Management System (ChRDMS) is sub-divided into two (2) subsystems: the client and admin subsystems. The client subsystem is the researcher's module while the admin subsystem keeps contact of researchers that are registered in the system. This ChRDMS passed the black box testing and the result is shown in the following subsections:

4.10.1 The chemists' subsystem

The following interfaces are available in the chemists' subsystem.

4.10.1.1 The splash screen

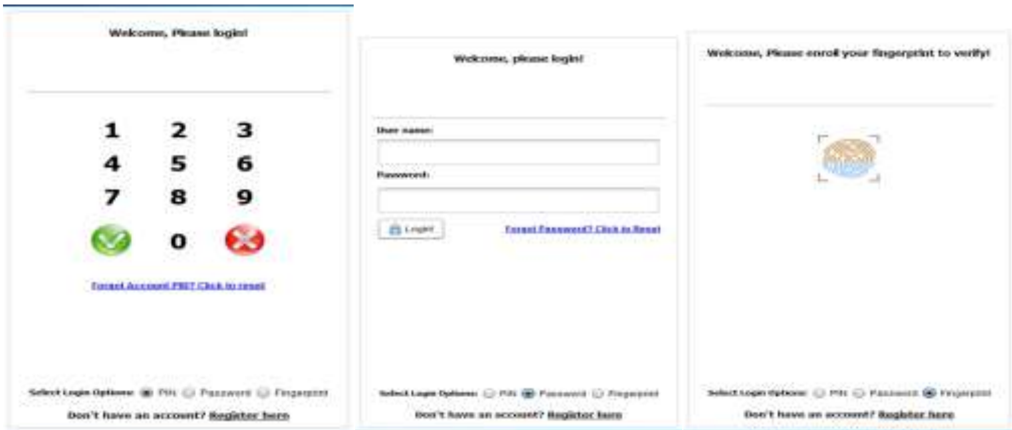
The splash screen is the first interface displayed when the application is running. The interface initialize connection to the database schema and the tables. It also loads all the modules in the application before launching the application. Figure 4.34 shows the splash screen of the ChRDMS:

Figure 4.34: Splash Screen

4.10.1.2 The start page

The start page is the second interface displayed by the application. It contains the registration and login modules of the application. This is shown in Figure 4.35. The login modules are in three options; either through PIN, Password or Fingerprint. These login modules are depicted in Figure 4.36:

Figure 4.35: Start Page



PIN Login Module Password Login Module Fingerprint Login Module

Figure 4.36: Login Module

4.10.1.3 The registration module

First, a user must establish connection to the admin system in order to register, or configure it from the registration link configuration wizard at the ‘***more options’*** popup menu at the bottom of the screen. The registration module is divided into two steps. Figure 4.37 shows Registration Module Step 1 while Figure 4.38 shows the Step 2:

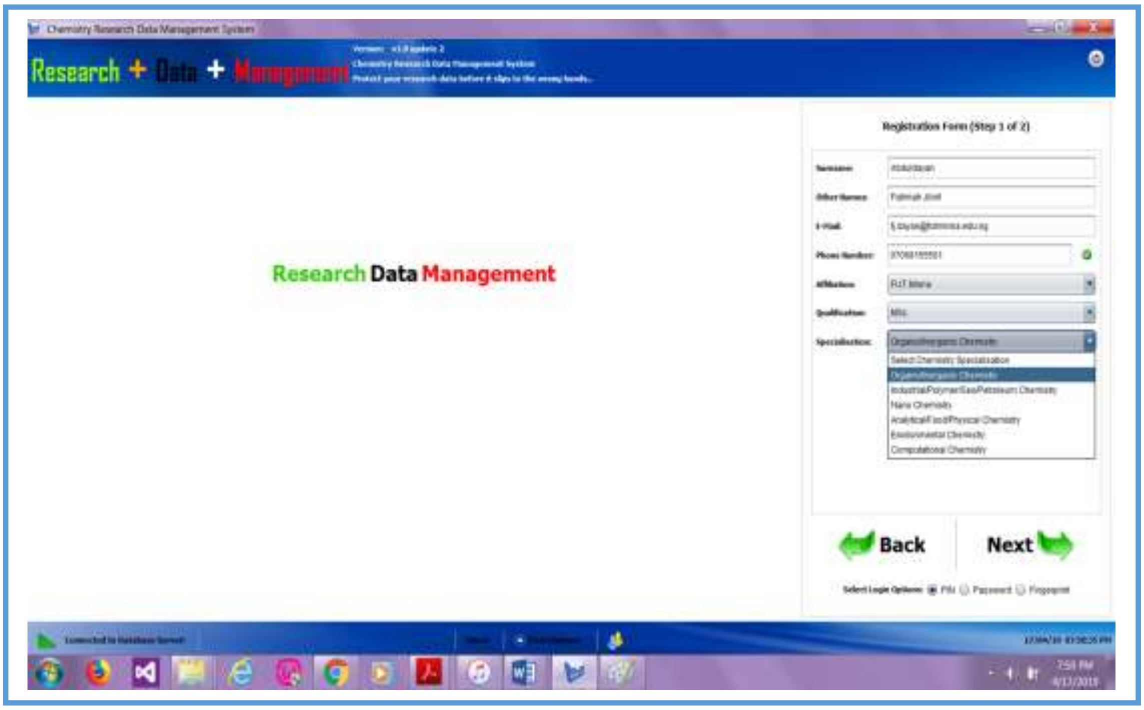


Figure 4.37:Registration Module Step 1

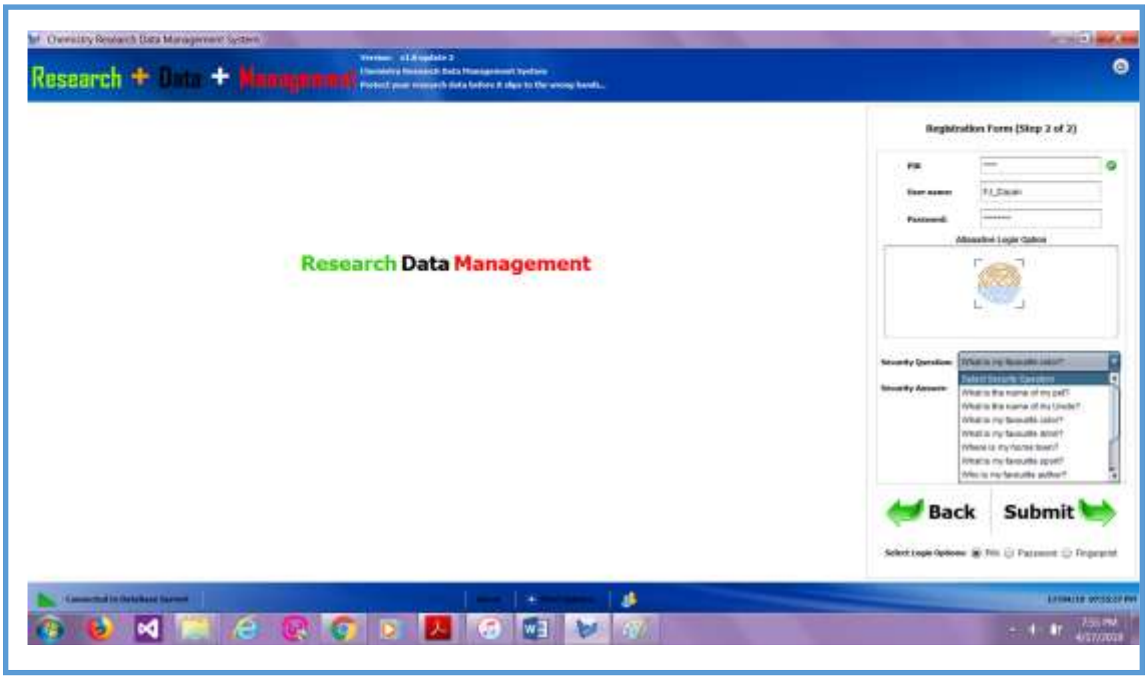


Figure 4.38:Registration Module Step 2

4.10.1.4 The main menu

This is the main interface of the application where users can access all the other functions of the application. This is shown in Figure 4.39:

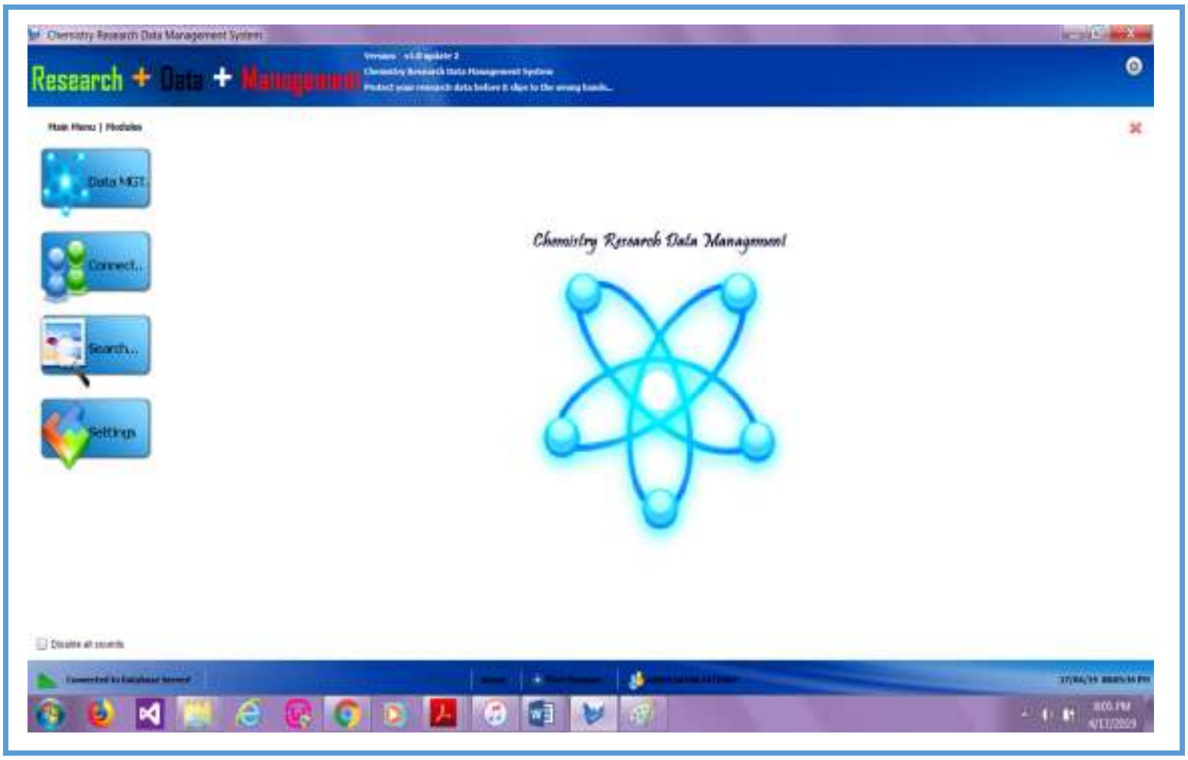


Figure 4.39:The Main Menu

4.10.1.5 Research data management interface

At the click of a button, the main module first option displays the research data management interface where users can store their research data and manage it adequately. This is shown in Figure 4.40:

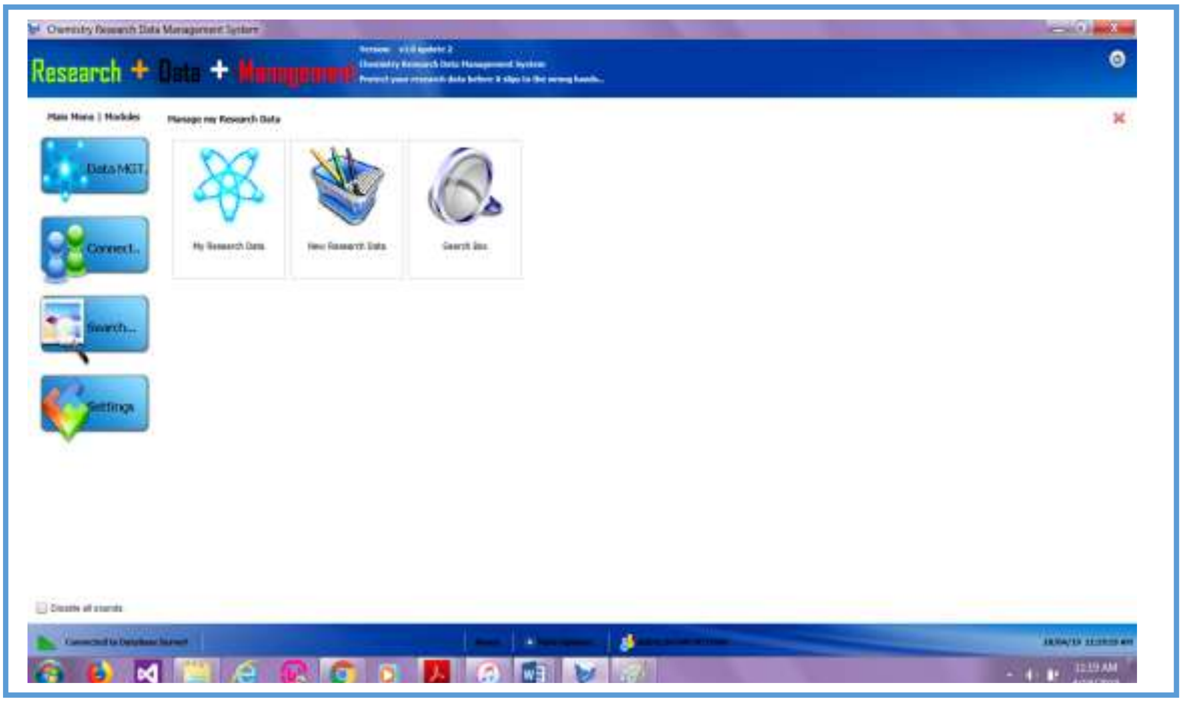


Figure 4.40: Research Data Management Interface

4.10.1.6 New research data interface

The first step in creating a new research is to select the chemistry options/categories from the drop-down menu as shown on Figure 4.41(a), then fill the forms from step 1 to the end as shown in Figure 4.41(b):

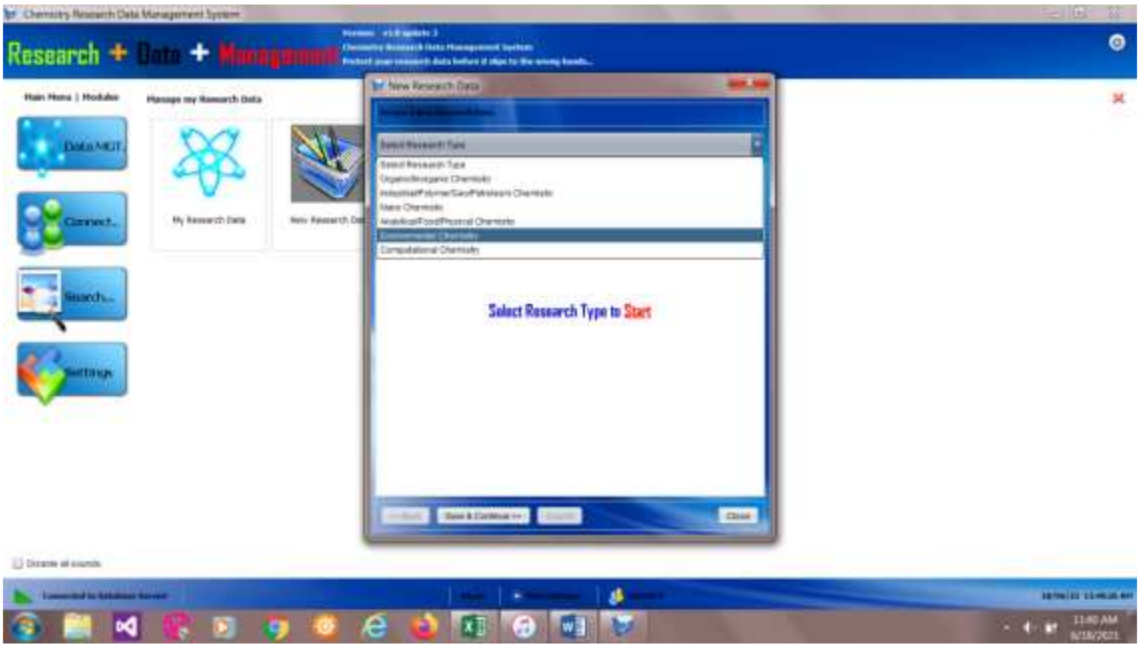


Figure 4.41(a): New Research Data Interface (all options)

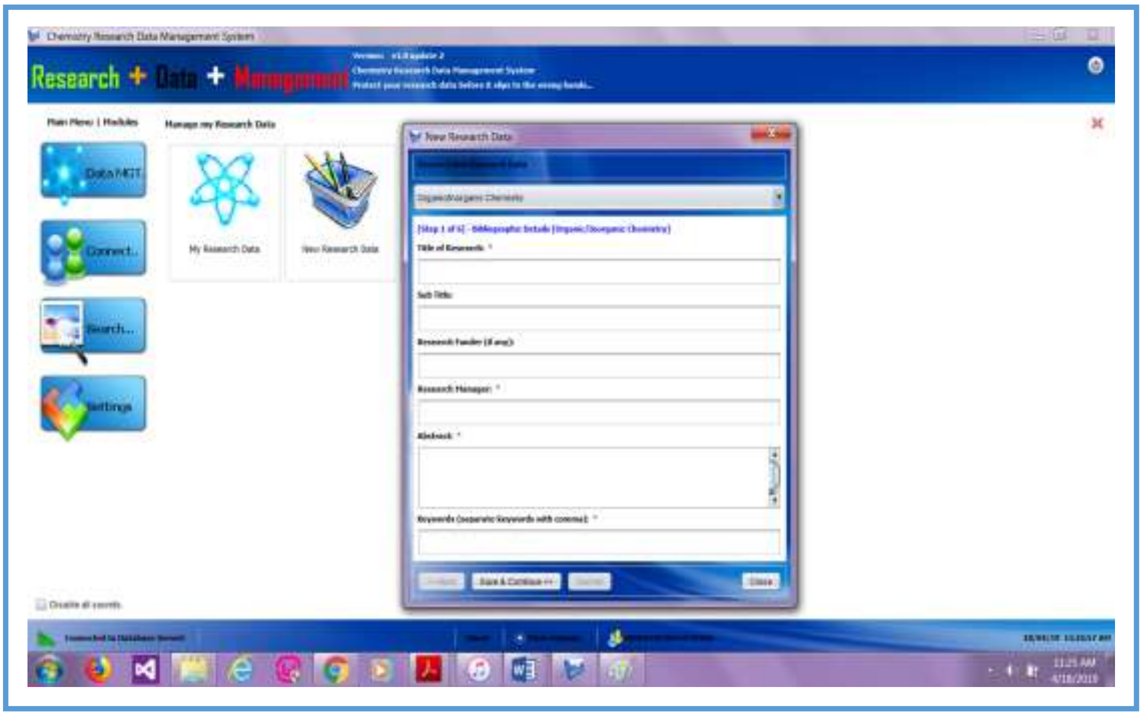


Figure 4.41(b):New Research Data Interface(specific option)

4.10.1.7 Research data database

This is a list of all the researches stored on the system. From this interface, the researcher can edit, view, export and print the research data. It also incorporates a search box to facilitate easy accessibility as shown in Figure 4.42:

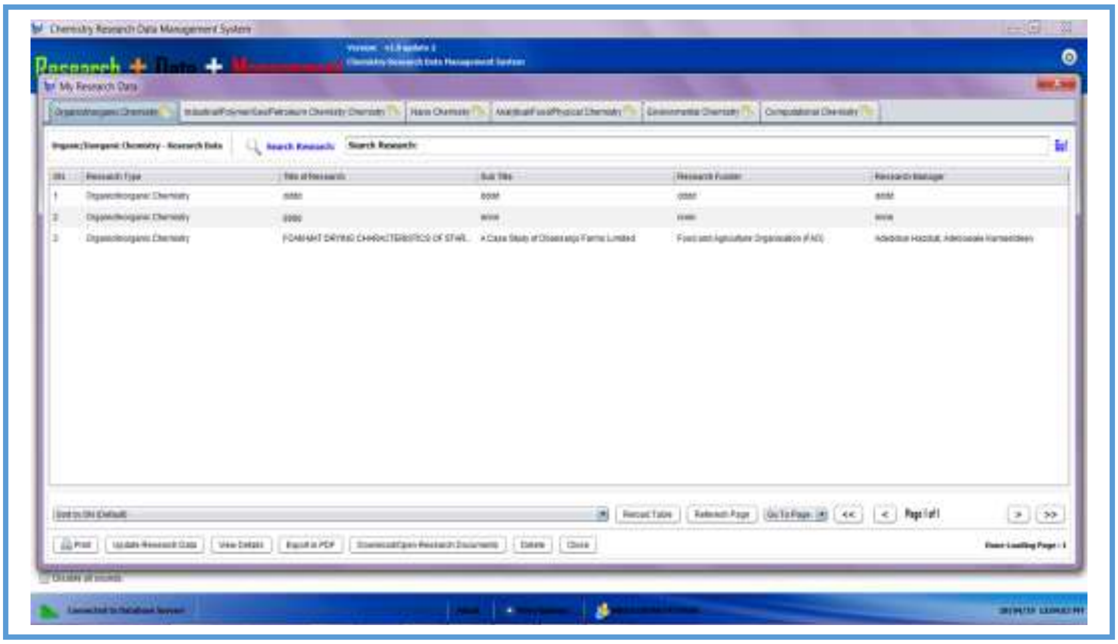


Figure 4.42: Research Data Database

4.10.1.8 Library connections

This interface links to various library websites/home page or the institutional repositories where it is available. Researchers can also archive their research data as the need arises. The screenshot is shown in Figure 4.43:

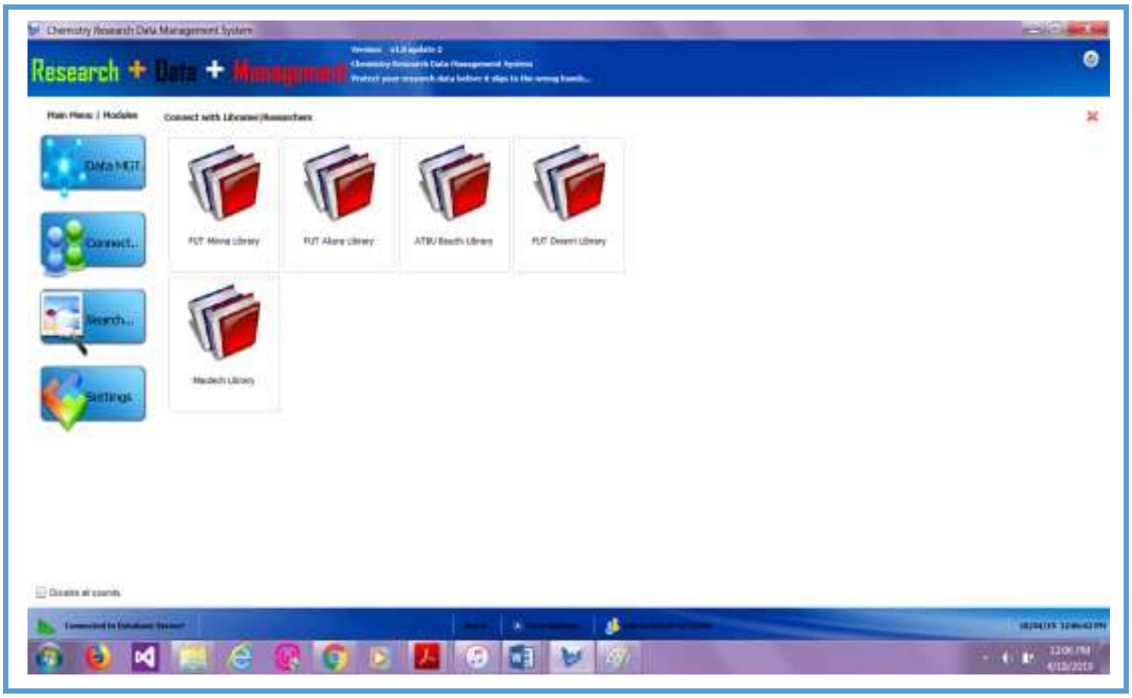


Figure 4.43:Library Connections

4.10.1.9 The search box/wizard

The search wizard facilitates easy accessibility of stored research data in the database. It also enables connections to public DMPs and interface search as shown in Figure 4.44:

Figure 4.44: Search Box/Wizard

4.10.1.10 The settings module

The module contains functions to change account profile, login credentials, database backup and restores user manual and security tracking/monitor as shown in Figure 4.45:

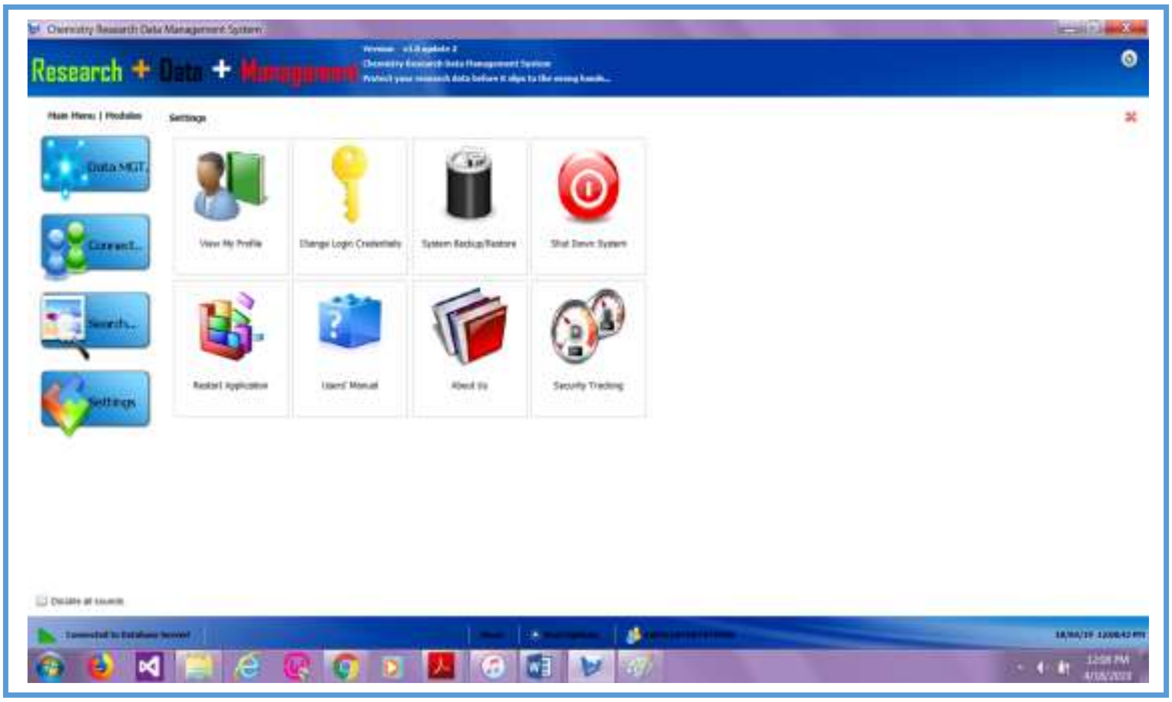


Figure 4.45:Settings Module

4.10.1.11 Changing login credentials

A user can change his/her user name/password, PIN or Fingerprint pattern by providing the current details. Furthermore, a user can reset his/her user name/password or PIN at the login module if it is forgotten. This is depicted in Figure 4.46:

Figure 4.46: Login Credential Update

4.10.1.12 Database backup/restore

The ChRDMS enables database and research data documents backup to external storage media. In case of emergencies, the backup file can be restored to the system conveniently. In a situation where a user lost his/her system or it got crashed/damaged, the user can acquire a new system install the Research Data Management System application software, thereafter an ‘emergency database restore’ should be done from stored backup files. The emergency restore will be done without registering the system again. It should be added that the backup is stored in two (2) files: an SQL backup file and a zip file containing the research documents. This is shown in Figures 4.47 and 4.48:

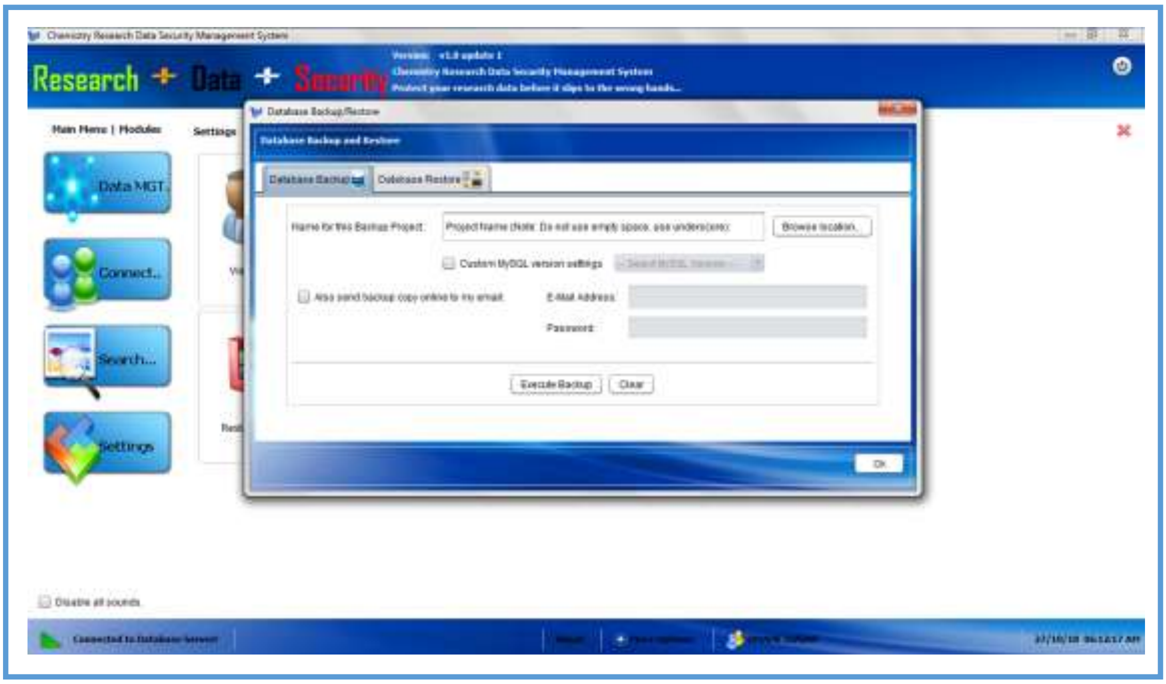


Figure 4.47: Database Backup/Restore

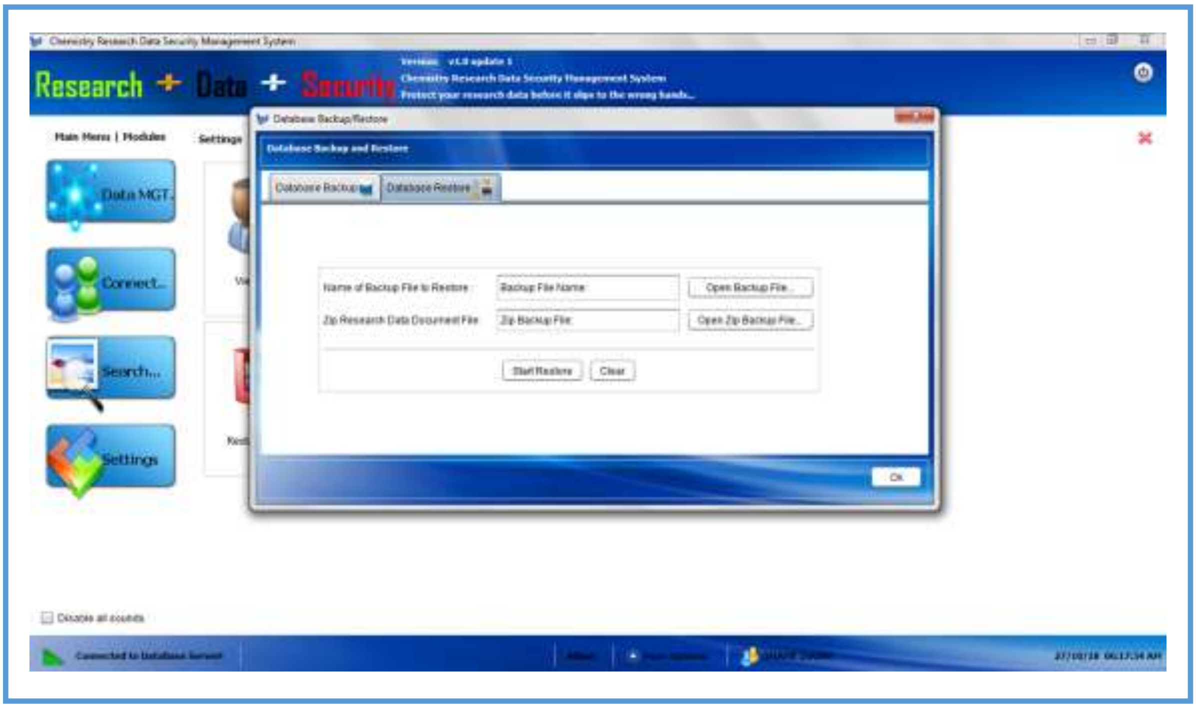


Figure 4.48: Database Restore

4.10.1.13 Security tracking/monitor

This module of the application keeps track of activities carried out by users. It is observed that some researchers employ student-research assistants to assist them to type and do some computer work. The research assistants should also be registered to have his/her account to the application so that the main researcher can monitor activities done by his/her research assistants as shown in Figure 4.49:

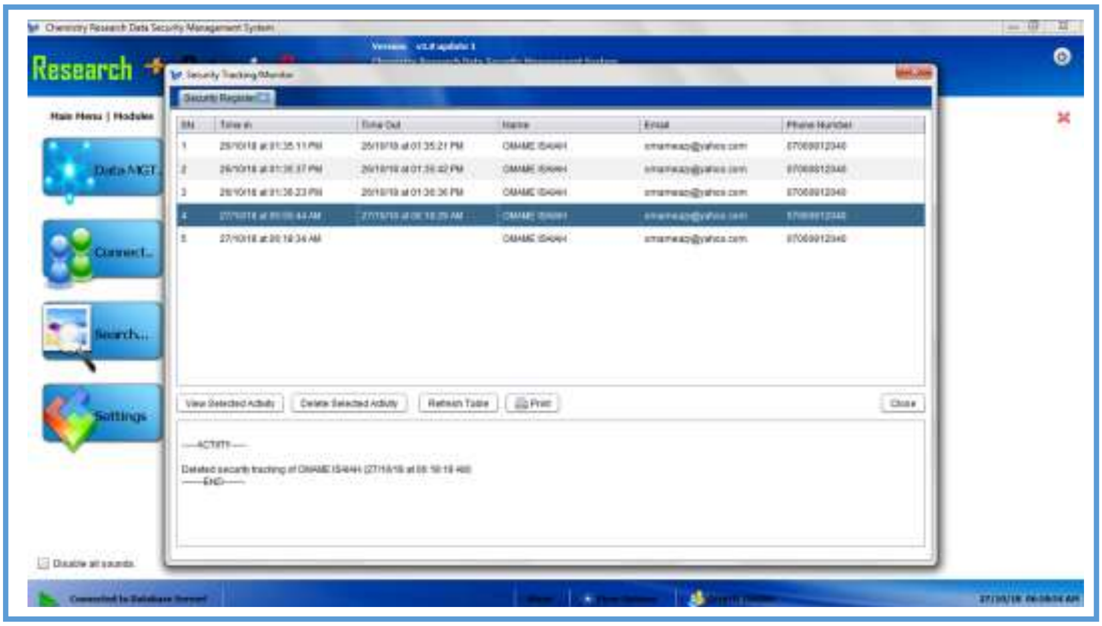


Figure 4.49: Security Tracking/Monitor

4.10.1.14 About, license and contact

The Figure 4.50 of the application contains information about the application, license agreements/terms and contact of the developers.

Figure 4.50: About, License and Contact

4.10.2 The admin subsystem

The following interfaces are available in the admin subsystem.

4.10.2.1 The login interface

Figure 4.51 shows the admin login interface:

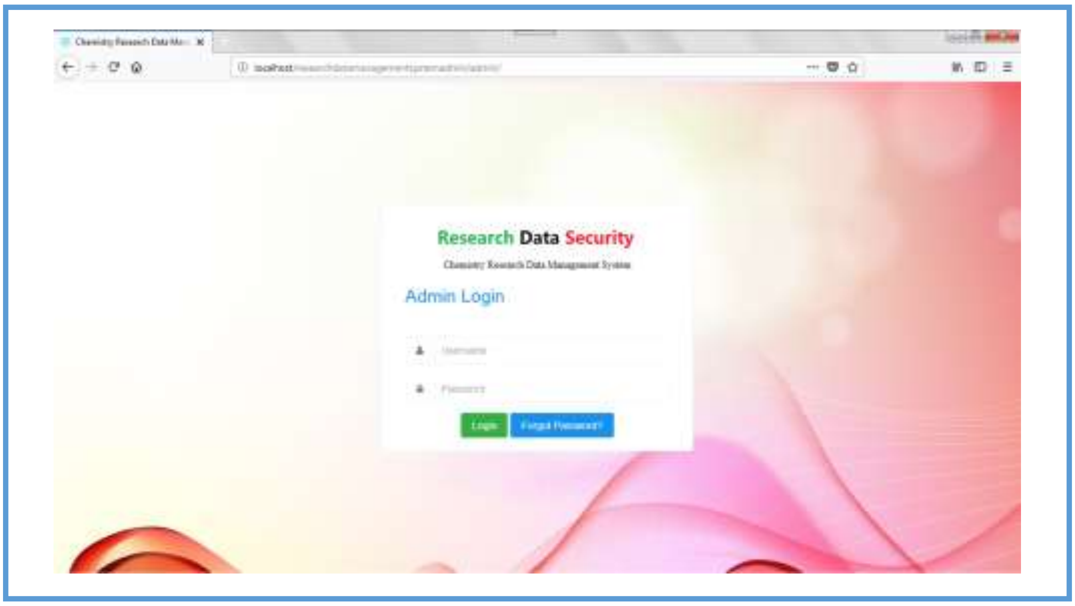


Figure 4.51: Admin Login Interface

4.10.2.2 The dashboard

This interface shown on Figure 4.52 gives access to all the section of the application:

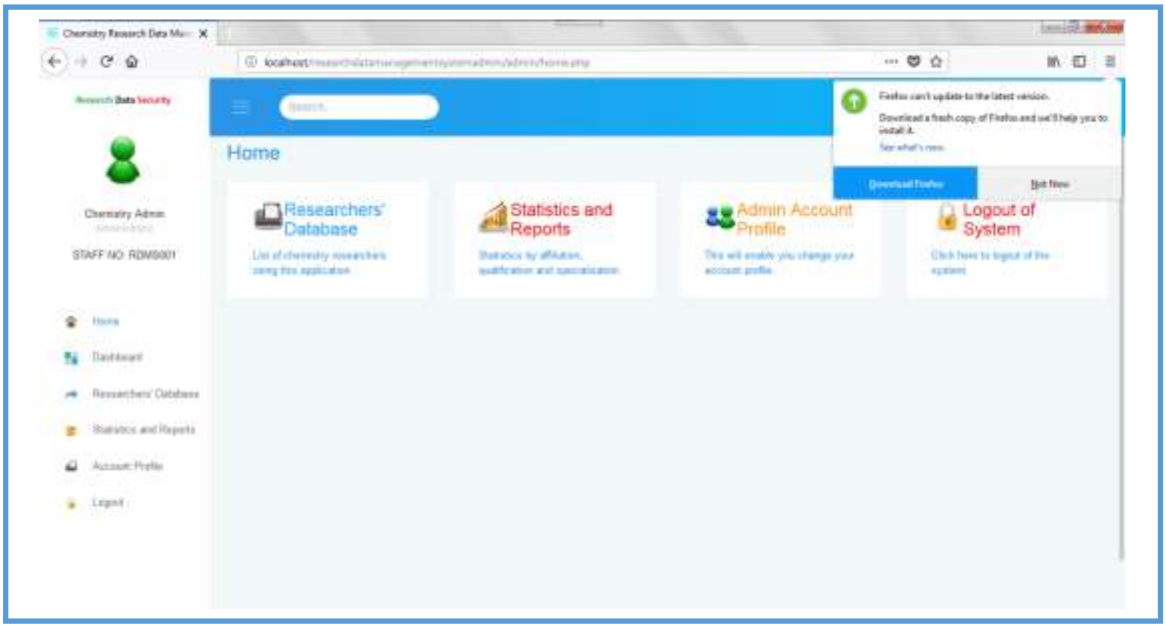


Figure 4.52: Dashboard

4.10.2.3 Chemists database

Figure 4.53 shows the database of all chemists that have registered in the system. This is to enable the organization to contact the researchers and send them notification of updated versions of the application.

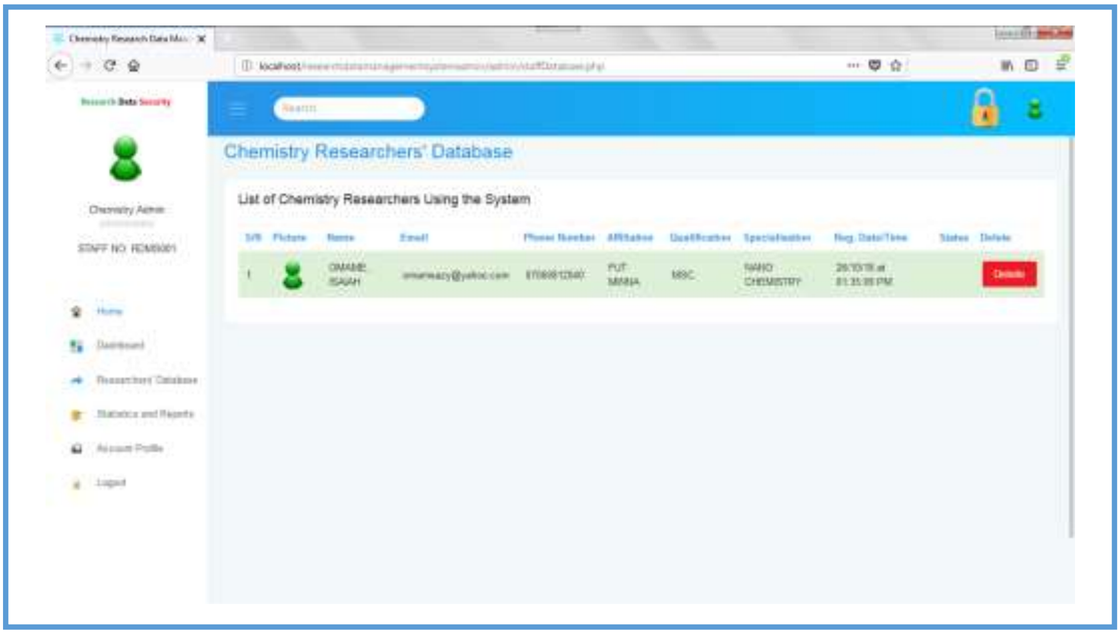


Figure 4.53: Chemists Database

4.10.2.4 Researchers’ statistics

The splash screen in Figure 4.54 shows the statistical charts of the chemists by affiliation, qualification and specialization. This will the admin to see at a glance, the number of users, affiliation, qualification and specialization. Offering support services and making forecasts is easier from this module.

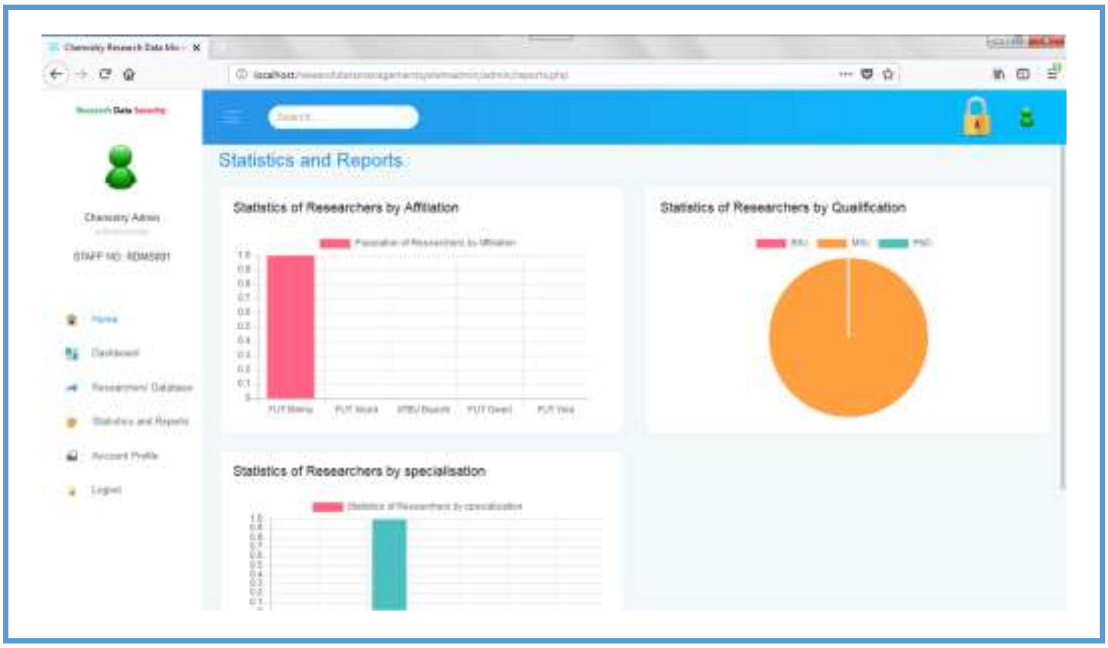
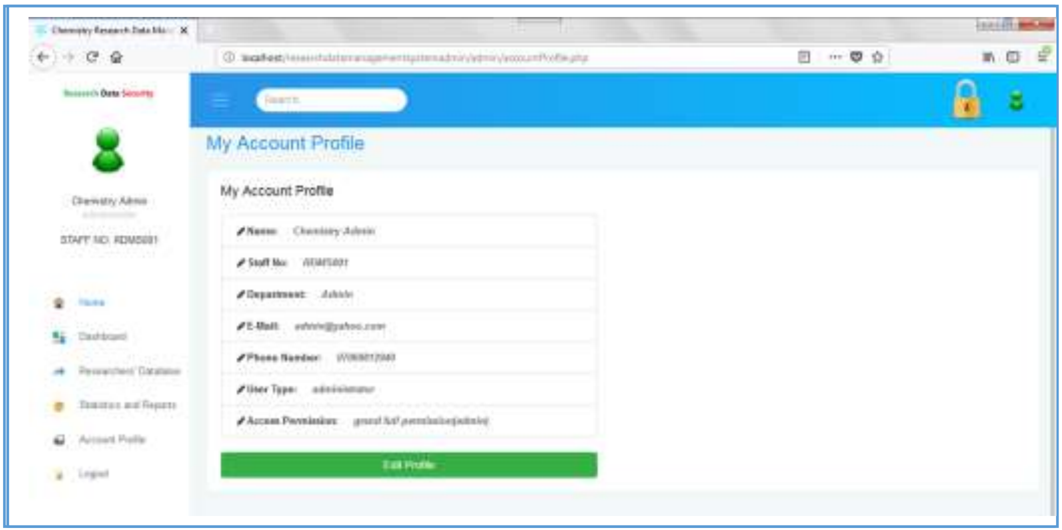


Figure 4.54: Researchers’ Statistics

4.10.2.5 View/update account profile

The interface shown in Figure 4.55 enables the admin to view and update his/her account profile. Other personal settings and privileges could also be assigned as deemed necessary. Finally, Figure 4.56 shows a screenshot of a sample final research data output (dataset) that could be downloaded in PDF or DOC format for safe keep,



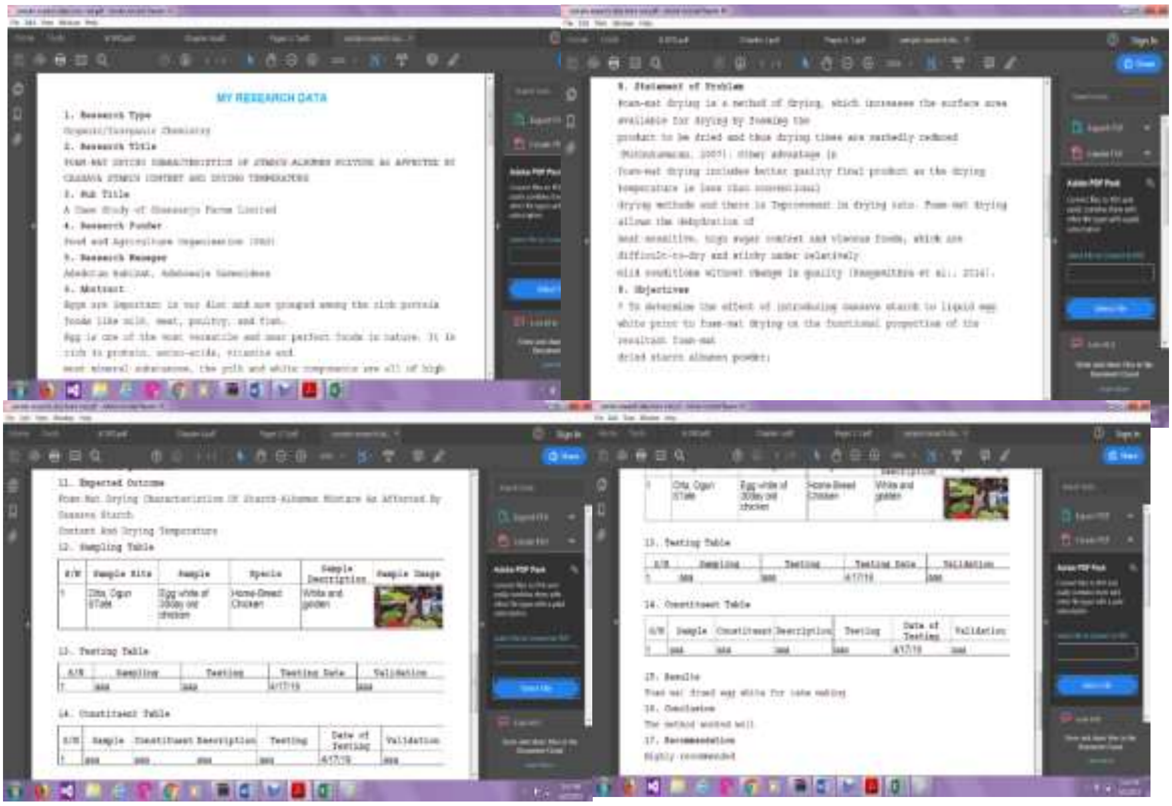
or forwarded to the institutional repository for long-term preservation and sharing.

Figure 4.55: View/Update Account Profile
Figure 4.56: Screenshots of a Sample Research Data

4.11 Limitations of the developed research data management prototype

The prototype is limited to only chemistry research and chemists in the five federal universities of technology used during the developmental stage and for acceptance testing.

Research Question 3: What is the behavioural intention of chemists towards



acceptance and use of the developed computer-based data management model?

4.12 Technology acceptance testing

The developed chemistry research data management system was subjected to an acceptance testing process. This process involves chemists to actually use and interact with the software with the aim of commenting, criticising and determining whether the software fits into their existing research workflow. An adapted questionnaire, based on the constructs of the Unified Theory of Acceptance and Use of Technology (Venkatesh *et al*, 2003), was distributed to chemists which was filled and returned. The aim of the questionnaire was to determine the behavioural intention of chemists towards the actual use of the ChRDMS prototype. Sixty four (64) chemists covering various ranks (Lecturer II-Professor) and options (analytical, organic, inorganic, industrial, polymer, food, nano, physical, environmental, etc.) in chemistry were part of the acceptance testing process. This took place in Federal University of Technology, Minna; Federal University of Technology, Akure; Abubakar Tafawa Balewa University, Bauchi; Federal University of Technology, Owerri; and Modibbo Adama University of Technology, Yola, within the period August 5^{th}– September 19^{th}, 2019.

The researcher sent an official letter of request to the fiveheads of chemistry departments in FUTs in Nigeria and an agreed date for training the chemists on how to use the developed ChRDMS prototype was given. Training took place at an agreed venue and place like in thechemistry laboratories,during departmental board meetings,and at their individual offices.After the training and interactive sessions, the researcher shared copies of the questionnaire to the participants which were filled and returned immediately for further analysis.

4.13 The study framework and questionnaire analysis

The study framework (Author's concept) in Figure 4.57 was derived from the Unified Theory of Acceptance and Use of Technology model (Venkatesh *et al.*, 2003) to guide the study. The developed questionnaire wasanalysed todetermine the degree of association between "external variables" and "control variables" and their influence on "behavioural intention" to use the developed ChRDMS prototype.

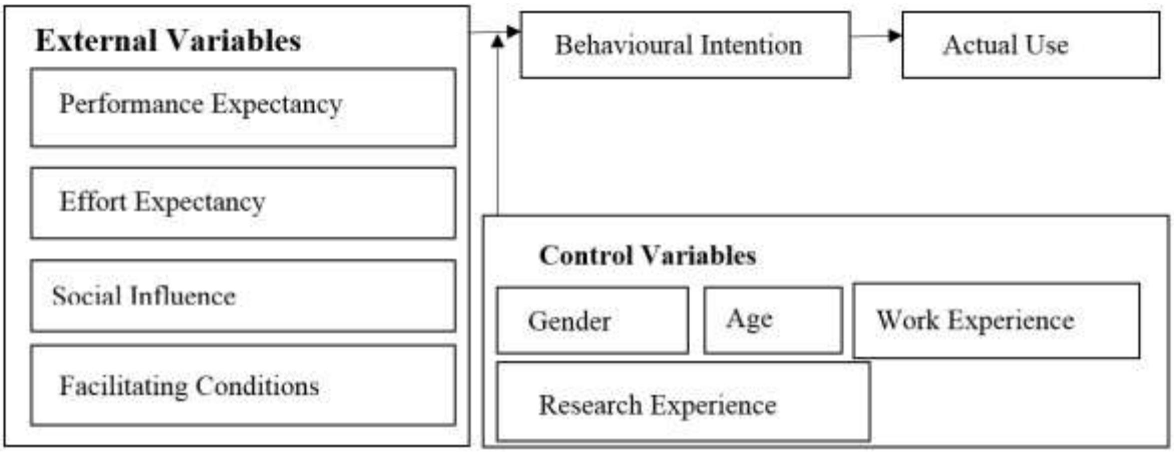


Figure 4.57: The Study Framework

4.14 Questionnaire data analysis

4.14.1 Response rate

A total number of thirty three (64) copies of the questionnaire were distributed to chemists in the five federal universities of technology in Nigeria to determine their behavioural intention to actual use of the ChRDMS. The questionnaire was adequately filled and returned and Table 4.3 presents the breakdown of response rate across the universities:

Table 4.3: Questionnaire Response Rate in the Three FUTs in Nigeria

S/N	INSTITUTIONS	RESPONSE RATE	PERCENTAGES (%)
1	FUTA	14	21.87%
2	ATBU	8	12.5%
3	FUTMIN	11	17.19%
4	FUTO	20	31.25%
5	MAUTECH	11	17.19%

	TOTAL	64	100%

Source: Field Survey(2021)

Table 4.3 shows the response rate in each institution. A total of 14(42%) respondents were from FUTA, 8(24%) respondents were from ATBU, 11(33%)respondents from FUTMIN, 20(31.25%) from FUTO and 11(17.19%) from MAUTECH.

4.14.2 Gender distribution

Table 4.4: Gender Distribution of Chemists in FUTs in Nigeria

Gender	FUTA	ATBU	FUTMIN	FUTO	MAUTECH
Male	10(71%)	6(75%)	9(82%)	9(45%)	6(55%)
Female	4(29%)	2(25%)	2(18%)	11(55%)	5(55%)
Total	**14(100%)**	**8(100%)**	**11(100%)**	**20(100%)**	**11(100%)**

Table 4.4 shows the gender distribution of chemists in the three FUTs under study. FUTA had the highest number of male respondents of 10(71%), while FUTO had the highest female respondents of 11(55%). ATBU had 6(75%) male respondents and 2(25%) female. FUTMIN had 9(82%) and also 2(18%) female respondents, MAUTECH had 6(55%) male respondents and 5(55%) female respondents.

4.14.3 Age distribution

Table 4.5: Age Distribution of Chemists in FUTs in Nigeria

Age	FUTA	ATBU	FUTMIN	FUTO	MAUTECH
25-35 years	2(14%)	1(12.5%)	4(37%)	2(10%)	1(9%)
36-45years	5(36%)	4(50%)	2(18%)	4(20%)	3(27%)
46-55years	5(36%)	2(25%)	3(27%)	8(40%)	4(37%)

55years and above	2(14%)	1(12.5%)	2(18%)	6(30%)	3(27%)
TOTAL	**14(100%)**	**8(100%)**	**11(100%)**	**20(100%)**	**11(100%)**

From the age distribution in Table 4.5, majority of respondents fell within the 36-45years and 46-55years age ranges.

4.14.4 Years of work experience

Table 4.6: Years of Work Experience by Chemists in FUTs in Nigeria

Work Experience	**FUTA**	**ATBU**	**FUTMIN**	**FUTO**	**MAUTECH**
5-10years	7(50%)	4(50%)	6(55%)	4(20%)	3(27%)
11-15years	2(14%)	1(12.5%)	-	3(15%)	4(37%)
16-20years	3(22%)	1(12.5%)	2(18%)	6(30%)	3(27%)
20years and above	2(14%)	2(25%)	3(27%)	7(35%)	1(9%)
TOTAL	**14(100%)**	**8(100%)**	**11(100%)**	**20(100%)**	**11(100%)**

As depicted in Table 4.6, majority of respondents from the FUTs under study had 5-10years of work experience. For those with 20years and above work experience, FUTA had 2(14%), ATBU 2(25%) and FUTMIN 3(27%), ATBU 7(35%) and MAUTECH 1(9%).

4.14.5 Years of research experience by chemists in FUTs

The last control variable as stated in the authors' study framework is the years of research experience. Research experience is relevant to understanding and appreciating the importance and benefits of effective research data management. Number of projects supervised, conference attendance and paper presentations, journal publications, book publications, and patented items or ideas was used to determine the research experience of chemists in FUTs. The year range under focus in this study was from 2014-2019.

Table 4.7: Years of Research Experience by Chemists in FUTs in Nigeria

Years of Research Experience	FUTA	ATBU	FUTMIN	FUTO	MAUTECH
Number of published article(s) within the year (2014-2019)	102	93	62	77	51
Number of supervised students theses and dissertations, within the year (2014-2019)	152	146	103	141	93
Number of conference papers presentation within the year (2014-2019)	58	32	48	51	47
Number of book publications within the year (2014-2019)	5	4	5	3	5
Number of patented research findings (2014-2019)	3	10	4	2	1
TOTAL	**320**	**285**	**222**	**274**	**197**

Table 4.7 shows the articles, supervised theses and dissertations form the highest source of research experience by chemists in FUTs in Nigeria. Book publication and patents form the least number of publications.

4.15 Data analysis using median and Kendall Tau-b statistic tool

4.15.1 Calculating the median using data points

Median score was computed and used to determine the central tendency so that decisions can be made on responses derived from chemists in federal universities of technology in Nigeria. The procedure and format used was as reported in Abifarin *et al.* (2019).

Appendix U shows the sorted data points of the five FUTs in ascending order. There were 23 items from the questionnaire, the data points represent the responses to each of the questionnaire items multiplied by the corresponding Likert scale figure. The study used the 5-point Likert scale from Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), and Strongly Disagree (1). The data points of individual universities with their median score is presented in Table 4.8:

Table 4.8: Data Points of Individual University with their Median

S/N	ATBU	FUTA	FUTMIN	FUTO	MAUTECH
1.	29	47	42	46	29
2.	30	52	42	51	29
3.	31	54	43	52	34

4.	32	54	43	55	34
5.	32	55	43	57	35
6.	33	56	43	58	36
7.	33	56	43	60	37
8.	33	57	44	63	39
9.	33	57	45	65	39
10.	33	57	46	68	40
11.	33	58	47	69	40
12.	**33**	**59**	**47**	**70**	**40**
13.	35	59	47	70	40
14.	35	59	48	72	40
15.	36	59	48	74	40
16.	36	60	49	76	43
17.	36	60	49	76	43
18.	37	61	50	78	44
19.	37	61	50	79	44
20.	37	62	51	79	46
21.	37	63	52	84	50
22.	38	64	52	87	51
23.	39	65	53	88	54

To determine the median, since there are 23 items from the questionnaire, the median was the figure that fell in 11.5^{th} (approximately 12^{th}) position of the data points. **This gave 33, 59, and 47 for ATBU, FUTA and FUTMIN while FUTO and MAUTECH had 70 and 40 respectively.**

4.15.2 Distribution of Agreed and Disagreed Items among Chemists

The median value derived from the data points was used to determine decision of chemists on each of the questionnaire items. The median value ($\bar{X}$) for FUTMIN was 47, hence, any questionnaire item total (FX) greater than 47 is ‘agreed’,and less than

47 is 'disagreed'. This decision rule also applies to ATBU, FUTA, FUTO, and MAUTECH. The decision for FUTMIN is shown further on Table 4.9:

Table 4.9: Distribution of Agreed and Disagreed Items among Chemists in FUTMIN

Items	SA = 5	A=4	N=3	D=2	SD=1	Total (FX)	$\bar{X}$ = 47	Decision (FUTMIN)
Performance Expectancy (PE)								
PE1: I find the prototype useful to my research workflow.	40	12	00	00	00	52	FX≥ $\bar{X}$	Agreed
PE2: Using the prototype enables me to manage research data more quickly.	30	20	00	00	00	50	FX≥ $\bar{X}$	Agreed
PE3: Using the prototype increases my research productivity.	15	20	06	02	00	43	FX< $\bar{X}$	Disagreed
PE4: Using the prototype increases my chances of publishing in impact factor journals.	05	40	00	00	00	45	FX< $\bar{X}$	Disagreed
Effort Expectancy (EE)								
EE1: My interaction with the prototype is clear and understandable.	30	20	00	00	00	50	FX≥ $\bar{X}$	Agreed
EE2: It is easy for me to become skilful at using the prototype.	35	16	00	00	00	51	FX≥ $\bar{X}$	Agreed
EE3: I find the prototype easy to use.	35	12	03	00	00	50	FX≥ $\bar{X}$	Agreed
EE4: Learning to operate the prototype is easy for me.	20	28	00	00	00	48	FX≥ $\bar{X}$	Agreed
Social Influence (SI)								
SI1: People who influence my behaviour think that I should use the prototype.	15	16	12	00	00	43	FX< $\bar{X}$	Disagreed
SI2: People who are important to me think that I should use the prototype.	10	20	12	00	00	42	FX< $\bar{X}$	Disagreed
SI3: Library will be helpful in the use of the prototype.	20	16	03	02	01	42	FX< $\bar{X}$	Disagreed
SI4: In general, the university will support use of the prototype.	10	24	09	00	00	43	FX< $\bar{X}$	Disagreed
Facilitating Conditions (FC)								

FC1: I have the resources necessary to use the prototype.	15	32	00	00	00	47	FX=$\bar{X}$	Agreed
FC2: I have the knowledge necessary to use the prototype.	00	40	03	00	00	43	FX< $\bar{X}$	Disagreed
FC3: The prototype is compatible with other systems I use.	15	20	09	00	00	44	FX< $\bar{X}$	Disagreed
FC4: A specific person (or group i.e. library and ICT unit staff members) is available for assistance with the prototype challenges.	10	28	03	02	00	43	FX< $\bar{X}$	Disagreed
Behavioural Intention to Use the System (BI)								
BI1: I intend to use the prototype in my subsequent researches.	20	24	03	00	00	47	FX= $\bar{X}$	Agreed
BI2: I predict I would use the prototype in my subsequent researches.	15	28	03	00	00	46	FX < $\bar{X}$	Disagreed
BI3: I plan to use the prototype in my subsequent researches.	45	08	00	00	00	53	FX ≥ $\bar{X}$	Agreed
Actual Use of Technology (AT)								
AT1: Using the prototype is a good idea.	40	12	00	00	00	52	FX ≥ $\bar{X}$	Agreed
AT2: The prototype makes research more interesting.	25	24	00	00	00	49	FX ≥ $\bar{X}$	Agreed
AT3: Using the prototype to manage my research data is fun.	20	24	03	00	00	47	FX = $\bar{X}$	Agreed
AT4: I like using the prototype for my data management plan	25	20	03	00	00	48	FX ≥ $\bar{X}$	Agreed
Total	**495**	**504**	**72**	**6**	**1**	**1078**		

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree

Table 4.10: Distribution of Agreed and Disagreed Items among Chemists in ATBU

Items	SA	A	N	D	SD	Total (FX)	$\bar{X}$=33	Decision (ATBU)
Performance Expectancy (PE)							$\bar{X}$	

PE1: I find the prototype useful to my research workflow.	03	02	03	00	00	32	$FX<\bar{X}$	Disagreed
PE2: Using the prototype enables me to manage research data more quickly.	01	07	00	00	00	33	$FX=\bar{X}$	Agreed
PE3: Using the prototype increases my research productivity.	04	04	00	00	00	36	$FX\geq\bar{X}$	Agreed
PE4: Using the prototype increases my chances of publishing in impact factor journals.	05	03	00	00	00	37	$FX\geq\bar{X}$	Agreed
Effort Expectancy (EE)							$\bar{X}$	
EE1: My interaction with the prototype is clear and understandable.	05	02	01	00	00	36	$FX\geq\bar{X}$	Agreed
EE2: It is easy for me to become skilful at using the prototype.	04	04	00	00	00	36	$FX\geq\bar{X}$	Agreed
EE3: I find the prototype easy to use.	02	02	04	00	00	30	$FX<\bar{X}$	Disagreed
EE4: Learning to operate the prototype is easy for me.	01	03	04	00	00	29	$FX<\bar{X}$	Disagreed
Social Influence (SI)								
SI1: People who influence my behaviour think that I should use the prototype.	05	03	00	00	00	37	$FX\geq\bar{X}$	Agreed
SI2: People who are important to me think that I should use the prototype.	02	05	01	00	00	33	$FX=\bar{X}$	Agreed
SI3: Library will be helpful in the use of the prototype.	05	03	00	00	00	37	$FX\geq\bar{X}$	Agreed
SI4: In general, the university will support use of the prototype.	03	05	00	00	00	35	$FX\geq\bar{X}$	Agreed
Facilitating Conditions (FC)								
FC1: I have the resources necessary to use the prototype.	04	03	01	00	00	35	$FX\geq\bar{X}$	Agreed
FC2: I have the knowledge necessary to use the prototype.	02	04	02	00	00	32	$FX<\bar{X}$	Disagreed
FC3: The prototype is compatible with other systems I use.	03	03	02	00	00	33	$FX=\bar{X}$	Agreed

Table 4.10 - continuation

FC4: A specific person (or group i.e. library and ICT unit staff members) is available for assistance with the prototype challenges.	01	05	02	00	00	31	$FX<\bar{X}$	Disagreed
Behavioural Intention to Use the System (BI)								
BI1: I intend to use the prototype in my subsequent researches.	06	02	00	00	00	38	$FX\geq\bar{X}$	Agreed
BI2: I predict I would use the prototype in my subsequent researches.	07	01	00	00	00	39	$FX\geq\bar{X}$	Agreed
BI3: I plan to use the prototype in my subsequent researches.	05	03	00	00	00	37	$FX\geq\bar{X}$	Agreed
Actual Use of Technology (AT)								
AT1: Using the prototype is a good idea.	02	05	01	00	00	33	$FX=\bar{X}$	Agreed
AT2: The prototype makes research more interesting.	03	03	02	00	00	33	$FX=\bar{X}$	Agreed
AT3: Using the prototype to manage my research data is fun.	02	05	01	00	00	33	$FX=\bar{X}$	Agreed
AT4: I like using the prototype for my data management plan	03	03	02	00	00	33	$FX=\bar{X}$	Agreed
Total	**78**	**80**	**26**	**0**	**0**	**788**		

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree

Table 4.11: Distribution of Agreed and Disagreed Items among Chemists in FUTA

Items	SA	A	N	D	SD	Total (FX)	$\bar{X} = 59$	Decision (FUTA)
Performance Expectancy (PE)								
PE1: I find the prototype useful to my research workflow.	08	05	01	00	00	63	$FX \geq \bar{X}$	Agreed
PE2: Using the prototype enables me to manage research data more quickly.	06	06	02	00	00	60	$FX \geq \bar{X}$	Agreed
PE3: Using the prototype increases my research productivity.	07	03	04	00	00	59	$FX \geq \bar{X}$	Agreed
PE4: Using the prototype increases my chances of publishing in impact factor journals.	06	06	02	00	00	60	$FX \geq \bar{X}$	Agreed
Effort Expectancy (EE)							$FX \geq \bar{X}$	
EE1: My interaction with the prototype is clear and understandable.	05	06	03	00	00	65	$FX \geq \bar{X}$	Agreed
EE2: It is easy for me to become skilful at using the prototype.	06	07	01	00	00	61	$FX \geq \bar{X}$	Agreed
EE3: I find the prototype easy to use.	04	07	03	00	00	57	$FX < \bar{X}$	Disagreed
EE4: Learning to operate the prototype is easy for me.	06	05	03	00	00	59	$FX \geq \bar{X}$	Agreed
Social Influence (SI)								
SI1: People who influence my behaviour think that I should use the prototype.	00	05	09	00	00	47	$FX < \bar{X}$	Disagreed
SI2: People who are important to me think that I should use the prototype.	01	08	05	00	00	52	$FX < \bar{X}$	Disagreed
SI3: Library will be helpful in the use of the prototype.	04	07	03	00	00	57	$FX < \bar{X}$	Disagreed
SI4: In general, the university will support use of the prototype.	04	06	04	00	00	56	$FX < \bar{X}$	Disagreed
Facilitating Conditions (FC)								
FC1: I have the resources necessary to use the prototype.	04	08	02	00	00	58	$FX = \bar{X}$	Disagreed
FC2: I have the knowledge necessary to use the prototype.	04	07	03	00	00	57	$FX < \bar{X}$	Disagreed
FC3: The prototype is compatible with other systems I use.	03	06	05	00	00	54	$FX < \bar{X}$	Disagreed
FC4: A specific person (or group i.e. library and ICT unit staff members) is available for assistance with the prototype challenges.	02	08	04	00	00	54	$FX < \bar{X}$	Disagreed
Behavioural Intention to Use the System (BI)								
BI1: I intend to use the prototype in my subsequent researches.	02	09	03	00	00	55	$FX < \bar{X}$	Disagreed
BI2: I predict I would use the prototype in my subsequent researches.	04	09	01	00	00	59	$FX \geq \bar{X}$	Agreed

Table 4.11 - continuation

BI3: I plan to use the prototype in my subsequent researches.	06	07	01	00	00	61	FX≥X̄	Agreed
Actual Use of Technology (AT)								
AT1: Using the prototype is a good idea.	07	06	01	00	00	62	FX≥X̄	Agreed
AT2: The prototype makes research more interesting.	09	04	01	00	00	64	FX≥X̄	Agreed
AT3: Using the prototype to manage my research data is fun.	02	10	02	00	00	56	FX<X̄	Disagreed
AT4: I like using the prototype for my data management plan	05	07	02	00	00	59	FX≥X̄	Agreed
Total	**105**	**152**	**65**	**0**	**0**	**1335**		

Key: SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree

Table 4.12: Distribution of Agreed and Disagreed Items among Chemists in FUTO

Performance Expectancy (PE)	(SA)5	(A)4	(U)3	(D)2	(SD)1	EFX	**X̄ = 70**	**Decision (FUTO)**
PE1: I find the prototype useful to my research workflow.	3	7	4	4	2	65	FX< X̄	Disagreed
PE2: Using the prototype enables me to manage research data more quickly.	0	4	7	5	4	51	FX< X̄	Disagreed
PE3: Using the prototype increases my research productivity.	1	6	5	8	0	56	FX<X̄	Disagreed
PE4: Using the prototype increases my chances of publishing in impact factor journals.	3	10	7	0	0	64	FX≥ X̄	Agreed
Effort Expectancy (EE)								
EE1: My interaction with the prototype is clear and understandable.	0	3	5	7	5	46	FX<X̄	Disagreed
EE2: It is easy for me to become skillful at using the prototype.	8	0	5	7	0	69	FX≥ X̄	Agreed
EE3: I find the prototype easy to use.	8	6	3	2	1	78	FX≥ X̄	Agreed
EE4: Learning to operate the prototype is easy for me.	8	7	5	0	0	83	FX≥ X̄	Agreed
Social Influence (SI)								
SI1: People who influence my behavior think that I should use the prototype.	0	7	5	6	2	57	FX< X̄	Disagreed
SI2: People who are important to me think that I should use the prototype.	7	10	3	0	0	84	FX≥ X̄	Agreed
SI3: Library will be helpful in the use of the prototype.	3	5	4	8	0	63	FX<X̄	Disagreed
SI4: In general, the	6	4	4	6	0	70	FX= X̄	Agreed

Table 4.12 - continuation

university will support use of the prototype.								
Facilitating Conditions (FC)								
FC1: I have the resources necessary to use the prototype.	5	12	0	0	3	76	FX≥ $\bar{X}$	Agreed
FC2: I have the knowledge necessary to use the prototype.	20	20	21	8	0	69	FX< $\bar{X}$	Agreed
FC3: The prototype is compatible with other systems I use.	10	7	3	0	0	87	FX≥ $\bar{X}$	Agreed
FC4: A specific person (or group) is available for assistance with the prototype challenges	6	4	6	3	2	72	FX> $\bar{X}$	Agreed
Behavioural Intention to Use the System (BI)								
BI1: I intend to use the prototype in my subsequent researches.	10	3	3	4	0	79	FX≥ $\bar{X}$	Agreed
BI2: I predict I would use the prototype in my subsequent researches.	8	5	5	2	0	79	FX≥ $\bar{X}$	Agreed
BI3: I plan to use the prototype in my subsequent researches.	5	6	5	0	4	68	FX< $\bar{X}$	Disagreed
Actual Use of Technology (AT)								
AT1: Using the prototype is a good idea.	6	6	4	2	2	72	FX≥ $\bar{X}$	Agreed
AT2: The prototype makes research more interesting.	5	3	0	12	0	61	FX< $\bar{X}$	Disagreed
AT3: Using the prototype to manage my research data is fun.	0	4	10	0	6	48	FX< $\bar{X}$	Disagreed
AT4: I like using the prototype for my data management plan (DMP)	2	4	5	5	4	55	FX< $\bar{X}$	Disagreed

Table 4.13: Distribution of Agreed and Disagreed Items among Chemists in MAUTECH

Performance Expectancy (PE)	**SA**	**A**	**N**	**D**	**SD**	**Total (FX)**	**$\bar{X}$ = 40**	**MAUTECH Decision**
PE1: I find the prototype useful to my research workflow.	2	5	2	2	0	40	FX= $\bar{X}$	Agreed
PE2: Using the prototype enables me to manage research data more quickly.	5	1	5	0	0	44	FX≥ $\bar{X}$	Agreed
PE3: Using the prototype increases my research productivity.	7	4	0	0	0	51	FX≥ $\bar{X}$	Agreed
PE4: Using the prototype increases my chances of publishing in impact factor journals.	6	5	0	0	0	50	FX≥ $\bar{X}$	Agreed
Effort Expectancy (EE)								
EE1: My interaction with the prototype is	2	4	3	2	0	39	FX< $\bar{X}$	Disagreed

Table 4.13 - continuation

clear and understandable.								
EE2: It is easy for me to become skillful at using the prototype.	8	0	0	0	3	11	FX≥ $\bar{X}$	Agreed
EE3: I find the prototype easy to use.	2	6	3	0	0	43	FX≥ $\bar{X}$	Agreed
EE4: Learning to operate the prototype is easy for me.	0	7	4	0	0	40	FX= $\bar{X}$	Agreed
Social Influence (SI)								
SI1: People who influence my behavior think that I should use the prototype.	0	0	7	4	0	29	FX< $\bar{X}$	Disagreed
SI2: People who are important to me think that I should use the prototype.	7	4	0	0	0	51	FX< $\bar{X}$	Disagreed
SI3: Library will be helpful in the use of the prototype.	3	5	1	2	0	42	FX= $\bar{X}$	Agreed
SI4: In general, the university will support use of the prototype.	1	4	6	0	0	39	FX< $\bar{X}$	Disagreed
Facilitating Conditions (FC)								
FC1: I have the resources necessary to use the prototype.	0	8	0	0	3	35	FX< $\bar{X}$	Disagreed
FC2: I have the knowledge necessary to use the prototype.	0	0	7	4	0	29	FX< $\bar{X}$	Disagreed
FC3: The prototype is compatible with other systems I use.	10	1	0	0	0	54	FX≥ $\bar{X}$	Agreed
FC4: A specific person (or group) is available for assistance with the prototype challenges	2	3	2	4	0	36	FX< $\bar{X}$	Disagreed
Behavioural Intention to Use the System (BI)								
BI1: I intend to use the prototype in my subsequent researches.	1	3	3	4	0	34	FX< $\bar{X}$	Disagreed
BI2: I predict I would use the prototype in my subsequent researches.	6	0	0	5	0	40	FX= $\bar{X}$	Agreed
BI3: I plan to use the prototype in my subsequent researches.	1	3	3	4	0	34	FX< $\bar{X}$	Disagreed
Actual Use of Technology (AT)								
AT1: Using the prototype is a good idea.	6	0	0	2	0	34	FX< $\bar{X}$	Disagreed
AT2: The prototype makes research more interesting.	5	2	3	0	1	43	FX>$\bar{X}$	Agreed
AT3: Using the prototype to manage my research data is fun.	8	0	0	3	0	46	FX≥ $\bar{X}$	Agreed
AT4: I like using the prototype for my data management plan (DMP)	6	2	0	3	0	44	FX≥ $\bar{X}$	Agreed

4.16 Hypotheses testing using Kendall's Tau-b Correlation Coefficient

Kendall's Tau-b correlation coefficient is used to measure the association that exists between two ranked variables which is the focus of this study, as the study measured the association between "external variables" in the study framework towards chemists' "behavioural intention" to use the data management prototype. To calculate Kendall Tau-b, the following formula was used:

$$\textbf{Tau b} = \frac{C-D}{C+D}; \qquad (4.1)$$

while

$$\mathbf{Z} = \frac{3*Tau\ b\sqrt{n(n-1)}}{\sqrt{2(2n+5)}} \qquad (4.2)$$

Where C = Concordant; and D = Discordant; and Z = statistical significance as shown in Table 4.14:

Table 4.14: Organised and Unorganised Concordance Table

Performance expectancy(organised)	Unorganised rank	Concordant (c)	Discordant (D)
26	32	2	1
32	26	2	0
40.5	45	0	1
45	40.5	Total=4	Total = 2

$$\text{Tau} = \frac{4-2}{4+2};\ \frac{2}{6}; \qquad (4.3)$$

$$\text{Tau b} = 0.333 \qquad (4.4)$$

$$Z = \frac{3*0.333\sqrt{4(4-1)}}{\sqrt{2(2(4)+5)}} = \frac{3*0.333\sqrt{12}}{\sqrt{26}} \qquad (4.5)$$

$$Z = .678 \qquad (4.6)$$

Using the above formula, which also coincides with the SPSS calculations of Kendall Tau-b, gave the results in the next section. The external variables, on the other hand, as derived from the UTAUT model (Venkatesh, 2003) are: performance expectancy, effort expectancy, social influence and facilitating conditions. They were defined thus:

Performance expectancy: the degree to which chemists believe that using the ChRDMS software prototype would improve his or her job performance.

Effort expectancy: the degree of simplicity associated with the use of the ChRDMS software prototype.

Social influence: the degree to which chemists perceive that others believe he or she should use the ChRDMS software prototype.

Facilitating conditions: the degree to which chemists believe that an organizational and technical infrastructure exist to support the use of the developed ChRDMS prototype.

4.16.1 FUTMIN

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.15: Kendall's Tau-b Correlations for H_{01}

			Performance expectancy	**Behavioural intention**
Kendall's tau_b (tb)	Performance expectancy	Correlation Coefficient	1.000	0.333
		Sig. (2-tailed)	0.000	0.602
		N	4	3
	Behavioural intention	Correlation Coefficient	0.333	1.000
		Sig. (2-tailed)	0.602	0.000
		N	3	3

Table 4.15 shows that there is a positive relationship between behavioural intention and performance expectancy among chemists in Federal University of Technology, Minna. The table further shows that the behavioural intention of chemists in FUTMIN

towards the use of the ChRDMS prototype is not significantly affected by their performance expectancy with:

Tb = 0.333; (4.7)

p = 0.602 (4.8)

Therefore, the null hypothesis is not rejected.

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.16: Kendall's Tau-b Correlations for H_{02}

			Behavioural intention	**Effort expectancy**
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)	0.000	0.221
		N	3	3
	Effort expectancy	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.221	0.000
		N	3	4

Table 4.16 shows that there is a positive relationship between effort expectancy and behavioural intentions. However, chemists' behavioural intention to use the data management model in FUTMIN is not significantly affected by their effort expectancy with:

Tb = 0.816; (4.9)

p = 0.221. (4.10)

Therefore, the null hypothesis is not rejected.

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by "social influence";

Table 4.17: Kendall's Tau-b Correlations for H_{03}

			Behavioural intention	**Social influence**
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	0.000
		Sig. (2-tailed)	0.000	1.000
		N	3	3
	Social influence	Correlation Coefficient	0.000	1.000
		Sig. (2-tailed)	1.000	0.000
		N	3	4

Table 4.17 revealed that chemists in FUTMIN behavioural intention to use the data management model is not significantly affected by their social influence with:

Tb = 0.000; (4.11)

p = 1.000. (4.12)

Therefore, the null hypothesis is not rejected.

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by "facilitating conditions";

Table 4.18: Kendall's Tau-b Correlations for H_{04}

			Facilitating condition	**Behavioural intention**
Kendall's tau_b	Facilitating condition	Correlation Coefficient	1.000	0.333
		Sig. (2-tailed)	0.000	0.602
		N	4	3
	Behavioural intention	Correlation Coefficient	0.333	1.000
		Sig. (2-tailed)	0.602	0.000
		N	3	3

Table 4.18 shows that the chemists' in FUTMIN's behavioural intention to use the data management model is not significantly affected by the facilitating condition with:

Tb =0.333; (4.13)

p = 0.602. (4.14)

Therefore, the null hypothesis is not rejected.

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.19: Kendall's Tau-b Correlations for H_{05}

			Actual use of technology	**Behavioural intention**
Kendall's tau_b	Actual use of technology	Correlation Coefficient	1.000	0.333
		Sig. (2-tailed)	0.000	0.602
		N	4	3
	Behavioural intention	Correlation Coefficient	0.333	1.000
		Sig. (2-tailed)	0.602	0.000
		N	3	3

Table 4.19 shows that chemists in FUTMIN actual use of the data management model is not significantly affected by their behavioural intentions with:

Tb = 0.333; (4.15)

p = 0.602. (4.16)

Therefore, the null hypothesis is not rejected.

4.16.2 ATBU

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.20: Kendall's Tau-b Correlations for H_{01}

			Performance expectancy	**Behavioural intention**
Kendall's tau_b	Performance expectancy	Correlation Coefficient	1.000	0.333
		Sig. (2-tailed)	0.000	0.602
		N	4	3
	Behavioural intention	Correlation Coefficient	0.333	1.000
		Sig. (2-tailed)	0.602	0.000
		N	3	3

Table 4.20 shows that chemists' behavioural intention to use the data management model in ATBU is not significantly affected by the performance expectancy with:

Tb = 0.333; (4.17)

p = 0.602. (4.18)

Therefore, **the null hypothesis is not rejected.**

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.21: Kendall's Tau-b Correlations for H_{02}

			Behavioural intention	Effort expectancy
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)	0.000	0.221
		N	3	3
	Effort expectancy	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.221	0.000
		N	3	4

Table 4.21 shows that chemists' behavioural intention to use the data management model in ATBU is not significantly affected by the effort expectancy with:

Tb = 0.816; (4.19)

p = 0.221. (4.20)

Therefore, **the null hypothesis is not rejected.**

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affectedby "social influence";

Table 4.22: Kendall's Tau-b Correlations for H_{03}

			Behavioural intention	Social influence
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)	0.000	0.221
		N	3	3
	Social influence	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.221	0.000
		N	3	4

Table 4.22 shows that chemists' behavioural intention to use the data management model in ATBU is not significantly affected by social influence with:

Tb = 0.816; (4.21)

p = 0.221. (4.22)

Therefore, **the null hypothesis is not rejected.**

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by "facilitating conditions";

Table 4.23: Kendall's Tau-b Correlations for H_{04}

			Behavioural intention	Facilitating condition
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	0.333
		Sig. (2-tailed)	0.000	0.602
		N	3	3
	Facilitating condition	Correlation Coefficient	0.333	1.000
		Sig. (2-tailed)	0.602	0.000
		N	3	4

Table 4.23 shows that chemists' behavioural intention to use the data management model in ATBU is not significantly affected by the facilitating condition with:

Tb = 0.333; (4.23)

p = 0.602. (4.24)

Therefore, **the null hypothesis is not rejected.**

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.24: Kendall's Tau-b Correlations for H_{05}

			Actual use of technology	Behavioural intention
Kendall's tau_b	Actual use of technology	Correlation Coefficient	0.000	0.000
		Sig. (2-tailed)	0.000	0.000
		N	4	3
	Behavioural intention	Correlation Coefficient	.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	3

Table 4.24 shows that chemists' actual use of the data management model in ATBU is significantly affected by their behavioural intentions with:

Tb = 0.000; (4.25)

p = 0.000. (4.26)

Therefore, **the null hypothesis is rejected.**

4.16.3 FUTA

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.25: Kendall's Tau-b Correlations for H_{01}

			Performance expectancy	**Behavioural intention**
Kendall's tau_b	Performance expectancy	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	4	3
	Behavioural intention	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	3

Table 4.25 shows that chemists' behavioural intention to use the data management model in FUTA is significantly affected by the performance expectancy with:

Tb = 1.00; (4.27)

p = 0.00. (4.28)

Therefore, **the null hypothesis is rejected.**

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.26: Kendall's Tau-b Correlations for H_{02}

			Behavioural intention	**Effort expectancy**
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	3
	Effort expectancy	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	4

Table 4.26 shows that chemists' behavioural intention to use the data management model in FUTA is significantly affected by the effort expectancy with:

Tb = 1.000; (4.29)

p = 0.000. (4.30)

Therefore, **the null hypothesis is rejected.**

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by "social influence";

Table 4.27: Kendall's Tau-b Correlations for H_{03}

			Behavioural intention	Social influence
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	3
	Social influence	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	4

Table 4.27 shows that chemists' behavioural intention to use the data management model in FUTA is significantly affected by the performance expectancy with:

Tb = 1.000; (4.31)

p = 0.000. (4.32)

Therefore, **the null hypothesis is rejected.**

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by "facilitating conditions";

Table 4.28: Kendall's Tau-b Correlations for H_{04}

			Behavioural intention	Facilitating condition
Kendall's tau_b	Behavioural intention	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	3
	Facilitating condition	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	3	4

Table 4.28 shows that chemists' behavioural intention to use the data management model in FUTA is significantly affected by facilitating condition with:

Tb = 1.000; (4.33)

p = 0.000. (4.34)

Therefore, **the null hypothesis is rejected.**

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.29: Kendall's Tau-b Correlations for H_{05}

			Actual use of technology	**Behavioural intention**
Kendall's tau_b	Actual use of technology	Correlation Coefficient	1.000	.333
		Sig. (2-tailed)	0.000	.602
		N	4	3
	Behavioural intention	Correlation Coefficient	.333	1.000
		Sig. (2-tailed)	.602	0.000
		N	3	3

Table 4.29 shows that chemists' actual use of the data management model in FUTA is not significantly affected by the chemists' behavioural intention with:

Tb = 0.333; (4.35)

p = 0.602. (4.36)

Therefore, **the null hypothesis is not rejected.**

4.16.4 FUTO

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.30: Kendall's Tau-b Correlations for H_{01}

Correlations				
			Behavioural Intention to Usethe System (BI)	**Performance Expectancy**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.000
		Sig. (2-tailed)		0.500
		N	3	3
	performance expectancy	Correlation Coefficient	0.000	1.000
		Sig. (2-tailed)	0.500	
		N	3	4

Table 4.30 shows that chemists' behavioural intention to use the data management model in FUTO is not significantly affected by their performance expectancy with:

Tb = 0.000; (4.37)

p =0.500. (4.38)

Therefore, **the null hypothesis is not rejected.**

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.31: Kendall's Tau-b Correlations for H_{02}

Correlations				
			Behavioural Intention to Use the System (BI)	**Effort Expectancy (EE)**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)		0.110
		N	3	3
	Effort Expectancy (EE)	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.110	
		N	3	4

Table 4.31 shows that chemists' behavioural intention to use the data management model in FUTO is not significantly affected by their effort expectancy with:

Tb = 0.816; (4.39)

p =0.110. (4.40)

Therefore, **the null hypothesis is not rejected.**

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by their "social influence";

Table 4.32: Kendall's Tau-b Correlations for H_{03}

Correlations			**Behavioural Intention to Use the System (BI)**	**Social Influence**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.000
		Sig. (2-tailed)		0.500
		N	3	3
	social influence	Correlation Coefficient	0.000	1.000
		Sig. (2-tailed)	0.500	
		N	3	4

Table 4.32 shows that chemists' behavioural intention to use the data management model in FUTO is not significantly affected by their social influence with:

Tb = 0.000; (4.41)

p =0.500. (4.42)

Therefore, **the null hypothesis is not rejected.**

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by their "facilitating conditions";

Table 4.33: Kendall's Tau-b Correlations for H_{04}

Correlations				
			Behavioural Intention to Use the System (BI)	**Facilitating Conditions**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)		0.110
		N	3	3
	facilitating condition	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.110	
		N	3	4

Table 4.33 shows that chemists' behavioural intention to use the data management model in FUTO is notsignificantly affected by facilitating conditions with:

Tb = 0.816; (4.43)

p =0.110. (4.44)

Therefore, **the null hypothesis is not rejected.**

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.34: Kendall's Tau-b Correlations for H_{05}

Correlations				
			Actual Use of Technology (AT)	**Behavioural Intention to Use the System (BI)**
Kendall's tau_b	Actual Use of Technology (AT)	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)		0.110
		N	4	3
	Behavioural Intention to Use the System (BI)	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.110	
		N	3	3

Table 4.34 shows that chemists' behavioural intention to use the data management model in FUTO is not significantly affected by their actual use of the technology with:

Tb = 0.816; (4.45)

p =0.110. (4.46)

Therefore, **the null hypothesis is not rejected.**

4.16.5 MAUTECH

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.35: Kendall's Tau-b Correlations for H_{01}

Correlations

			Behavioural Intention to Use the System (BI)	**performance expectancy**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.000
		Sig. (2-tailed)		0.500
		N	3	3
	performance expectancy	Correlation Coefficient	0.000	1.000
		Sig. (2-tailed)	0.500	
		N	3	4

Table 4.35 shows that chemists' behavioural intention to use the data management model in MAUTECH is not significantly affected by their performance expectancy with:

Tb = 0.000; (4.47)

p =0.500. (4.48)

Therefore, **the null hypothesis is not rejected.**

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.36: Kendall's Tau-b Correlations for H_{02}

Correlations

			Behavioural Intention to Use the System (BI)	**Effort Expectancy (EE)**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.500
		Sig. (2-tailed)		0.240
		N	3	3
	Effort Expectancy (EE)	Correlation Coefficient	0.500	1.000
		Sig. (2-tailed)	0.240	
		N	3	4

Table 4.36 shows that chemists' behavioural intention to use the data management model in MAUTECH is not significantly affected by their effort expectancy with:

Tb = 0.500; (4.49)

p =0.240. (4.50)

Therefore, **the null hypothesis is not rejected.**

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by their "social influence";

Table 4.37: Kendall's Tau-b Correlations for H_{03}

Correlations

			Behavioural Intention to Use the System (BI)	**social influence**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.000
		Sig. (2-tailed)		0.500
		N	3	3
	social influence	Correlation Coefficient	0.000	1.000
		Sig. (2-tailed)	0.500	
		N	3	4

Table 4.37 shows that chemists' behavioural intention to use the data management model in MAUTECH is notsignificantly affected by their social influence with:

Tb = 0.000; (4.51)

p =0.500. (4.52)

Therefore, **the null hypothesis is not rejected.**

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by their "facilitating conditions";

Table 4.38: Kendall's Tau-b Correlations for H_{04}

Correlations				
			Behavioural Intention to Use the System (BI)	**Facilitating Conditions**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (2-tailed)		0.110
		N	3	3
	facilitating condition	Correlation Coefficient	0.816	1.000
		Sig. (2-tailed)	0.110	
		N	3	4

Table 4.38 shows that chemists' behavioural intention to use the data management model in MAUTECH is not significantly affected by facilitating conditions with:

Tb = 0.816; (4.53)

p =0.110. (4.54)

Therefore, **the null hypothesis is not rejected.**

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.39: Kendall's Tau-b Correlations for H_{05}

Correlations

			Actual Use of Technology (AT)	**Behavioural Intention to Usethe System (BI)**
Kendall's tau_b	Actual Use of Technology (AT)	Correlation Coefficient	1.000	0.500
		Sig. (2-tailed)		0.240
		N	4	3
	Behavioural Intention to Use the System (BI)	Correlation Coefficient	0.500	1.000
		Sig. (2-tailed)	0.240	
		N	3	3

Table 4.39 shows that chemists' behavioural intention to use the data management model in MAUTECH is notsignificantly affected by their actual usage of the technology with:

$$Tb = 0.500; \quad (4.56)$$

$$p = 0.240. \quad (4.57)$$

Therefore, **the null hypothesis is not rejected.**

4.16.4 Group Hypotheses Testing in the Five FUTs

H_{01}: Chemists' behavioural intention to use the data management model is not significantly affected by their "performance expectancy";

Table 4.40: Kendall's Tau-b Correlations for Group Hypothesis Testing (H_{01})

Correlations

			Behavioural Intention to Use the System (BI)	**Performance Expectancy**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (1-tailed)		0.110
		N	3	3
	Performance Expectancy	Correlation Coefficient	0.816	1.000
		Sig. (1-tailed)	0.110	
		N	3	4

Table 4.40shows the relationship between behavioural intention and performance expectancy among chemists in federal universities of technology in Nigeria. The table further shows that the behavioural intention of chemists to use the developed research data management model is positively correlated with performance expectancy:

Tb = 0.816; (4.58)

This correlation is however not significant with:

p = 0.110. (4.59)

Therefore, **the null hypothesis is not rejected.**

H_{02}: Chemists' behavioural intention to use the data management model is not significantly affected by their "effort expectancy";

Table 4.41: Kendall's Tau-b Correlations for Group Hypothesis Testing (H_{02})

Correlations				
			Behavioural Intention to Use the System (BI)	**Effort Expectancy (EE)**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (1-tailed)		0.110
		N	3	3
	Effort Expectancy (EE)	Correlation Coefficient	0.816	1.000
		Sig. (1-tailed)	0.110	
		N	3	4

Table 4.41 shows the relationship between behavioural intention and effort expectancy among chemists. The table further shows that the behavioural intention of chemists to use the developed research data management model is positively correlated with effort expectancy having:

Tb = 0.816; (4.60)

This correlation is however not significant with:

p = 0.110. (4.61)

Therefore, **the null hypothesis is not rejected.**

H_{03}: Chemists' behavioural intention to use the data management model is not significantly affected by "social influence";

Table 4.42: Kendall's Tau-b Correlations for Group Hypothesis Testing (H_{03})

Correlations

			Behavioural Intention to Use the System (BI)	**Social Influence (SI)**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (1-tailed)		0.110
		N	3	3
	Social Influence (SI)	Correlation Coefficient	0.816	1.000
		Sig. (1-tailed)	0.110	
		N	3	4

Table 4.42 showsthe relationship between behavioural intention and social influence among chemists. The table further shows that the behavioural intention of chemists to use the developed research data management model is positively correlated with social influence with:

$Tb = 0.816;$ (4.62)

This correlation is however not significant at:

$p = 0.110.$ (4.63)

Therefore, **the null hypothesis is not rejected.**

H_{04}: Chemists' behavioural intention to use the data management model is not significantly affected by "facilitating conditions";

Table 4.43: Kendall's Tau-b Correlations for Group Hypothesis Testing (H_{04})

Correlations

			Behavioural Intention to Use the System (BI)	**Facilitating Conditions (FC)**
Kendall's tau_b	Behavioural Intention to Use the System (BI)	Correlation Coefficient	1.000	0.816
		Sig. (1-tailed)		0.110
		N	3	3
	Facilitating Conditions (FC)	Correlation Coefficient	0.816	1.000
		Sig. (1-tailed)	0.110	
		N	3	4

Table 4.43shows the relationship between behavioural intention and facilitating conditions among chemists. The table further shows that the behavioural intention of chemists to use the developed research data management model is positively correlated with facilitating conditions:

Tb = 0.816; (4.64)

This correlation is however not significant with:

p = 0.110. (4.65)

Therefore, **the null hypothesis is not rejected.**

H_{05}: Chemists' actual use of the data management model is not significantly affected by their behavioural intentions.

Table 4.44: Kendall's Tau-b Correlations for Group Hypothesis Testing (H_{05})

Correlations				
			Actual Use of Technology (AT)	**Behavioural Intention to Use the System (BI)**
Kendall's tau_b	Actual Use of Technology (AT)	Correlation Coefficient	1.000	0.000
		Sig. (1-tailed)		0.500
		N	4	3
	Behavioural Intention to Use the System (BI)	Correlation Coefficient	0.000	1.000
		Sig. (1-tailed)	0.500	
		N	3	3

Table 4.44 shows the relationship between actual use of technology and behavioural intention to use the system among chemists. The table further shows that there is no correlation between behavioural intention of chemists to use the developed research data management model and the actual use of the model with:

Tb = 0.000; (4.66)

This lack of correlation is howevernot significant with:

p = 0.500. (4.67)

Therefore, **the null hypothesis is not rejected.**

4.17 Discussion of Results

The results revealed that in FUTMIN, a larger percentage of chemists (57%) agreed to the questionnaire items aimed at determining their behavioural intention towards actual use of the developed data management model. However, hypotheses testing showed that chemists in FUTMIN are of the opinion that performance expectancy, effort expectancy, social influence and facilitating conditions hasno significant effect on their actual use of the developed data management model. This negates the popular findings of studies on behavioural intentions to use an information technology. The findings also negate the study of Salim (2012) that reported performance expectancy, effort expectancy, social influence, and facilitating conditions have significant effects on behavioural intentions. This result could be as a result of the inadequate awareness on the benefits of appropriate research data management practice. There is also poor awareness of the availability of necessary support for research data services that the library and ITS units could offer to researchers in these universities.

In ATBU, the opinion of chemists are similar to that of FUTMIN, although a larger percentage (78%) agreed to the questionnaire items. The chemists also opined that performance expectancy, effort expectancy, social influence, and facilitating conditions has no significant effect on their behavioural intention to use the data management model. However, if all these concerns are taken into considerations, they will no longer have any significant effect on the continued use of the model.

The situation in FUTA is different from what obtains in FUTMIN and ATBU. Here, 52% of chemists agreed to the questionnaire items while 48% disagreed. The hypotheses testing revealed that performance expectancy, effort expectancy, social influence and facilitating conditions has significant effect on their behavioural intention to use the model.These findings are supported by studies of (Venkatesh *et* *al.*, 2003; Šumak & Šorgo, 2016; Hoque & Sorwar, 2017; Khalilzadeh *et al.*, 2017; Šumak *et al.*, 2017) who noted that performance expectancy, effort expectancy, social influence and facilitating condition have significant effects on behavioural intention to use any information system.

Another reason for this finding could be the fact that FUTA chemists had the largest figure for published articles (102), supervised students' projects, theses and dissertations (152), as well as conference papers (58) within the period under study. Chemists in FUTA also had quite a number of book publications and patents. These research experiences meant that chemists must have encountered some unforgettable experience of data loss, software and hardware incompatibility issues and bad storage devices. Hence, a computer-based data management solution is a readily acceptable option due to their previous research experience. In this case, research experience can be said to the strongest predictor of behavioural intentions contrary to previous studies. This position is supported by Chirara (2018) who revealed that, "The correlation between experience and usage behaviour was relatively strong and positive contrary to studies by Venkatesh *et al.* (2012) that suggested that behavioural intention was the strongest predictor".

The findings in FUTO and MAUTECH are similar to what obtains in FUTMIN and ATBU. Performance expectancy, effort expectancy, social influence and facilitating conditions all had no significant effects on the behavioural intentions to actual use of the developed research data management system.

4.18 Summary of Findings

This summary is based on the findings derived from the achievement of the objectives that guided the study. The perception of chemists on research data management are:

1. chemists had a clear understanding of data as raw facts but the meaning of research data was not clear to them as they were yet to fully appreciate the importance of effective research data management generated across their research lifecycle;
2. chemists did not have a clearly defined data naming system making it difficult to retrieve stored data which eventually led to data loss;
3. improper choice of storage device has led to irrecoverable loss of data and in some cases, backup were either not created or not accessible as a result of limited knowledge on different storage media and backup methods;
4. password, Personal Identification Numbers (PINs), use of lock and keys were the methods of data protection and security by chemists;
5. hardware and software compatibility issues were also a setback to research data management among chemists;
6. chemists were willing to share only analysed data after publication with other chemists around the World provided due acknowledgement is done and proper citation is accorded. They were also not aware of intellectual property rights as regards research data and sharing;
7. chemists were aware of the open movements (open access, open data, open science) especially the open access. While majority of them supported the movement, some said Nigeria is not ready to adopt the open data principle;
8. library is the most preferred place for long-term storage and preservation of research data. This opinion was unanimously agreed upon by chemists in federal universities of technology in Nigeria;

9. Data Management Plan (DMP) was not being implemented during chemists' research process. However, if motivated, chemists were willing to adopt a DMP that is relevant to their research process.

Perception on the development and acceptance testing of a computer-based research data management model include:

10. chemists in federal universities of technology in Nigeria opined that a computer-based research data management software would help to create awareness and guide them on effective data management. This prototype must however, be secured, easy to use, and relevant to their existing research process;
11. The study developed a computer-based data management model and was tested for acceptance and continued use by chemists in federal universities of technology in Nigeria. The software model was found relevant and usable provided performance expectancy, effort expectancy, social influence, and facilitating conditions remain favourable;
12. Research experience has a strong and positive correlation with behavioural intention and actual usage of the developed research data management model.

Based on the foregoing, the study proposed a framework for libraries to follow in implementing a research data management service in their host universities.

Research Question 4: How can libraries in FUTs in Nigeria incorporate research data management services for enhanced chemistry research?

4.19 Proposed Framework for Incorporating Research Data Management Services by Libraries in FUTs in Nigeria.

The findings from this study gave a headway for libraries to follow in developing a research data management service for researchers in their host institutions. In developing a sustainable research data service, there is the need to conduct an initial qualitative study using interview and observation methods. This should be aimed at understanding the existing research data management practices of researchers/university under study. It will also assist in having a clear picture of their research process and workflow so that the proposed research data management service will readily fit into the system. Considerations should also be given to stakeholders that are relevant to the successful implementation of the RDM services. These stakeholders are the university management, library, ITS unit, and research office. Awareness, education and tracking of the deployed services is very crucial to ensure sustainability. A robust feedback systemshould also be designed to allow for criticism and possible areas of improvement.

These background information, along with other findings from this study, were used to propose the framework in Figure 4.58 for libraries to adopt in incorporating research data management services in federal universities of technology in Nigeria.

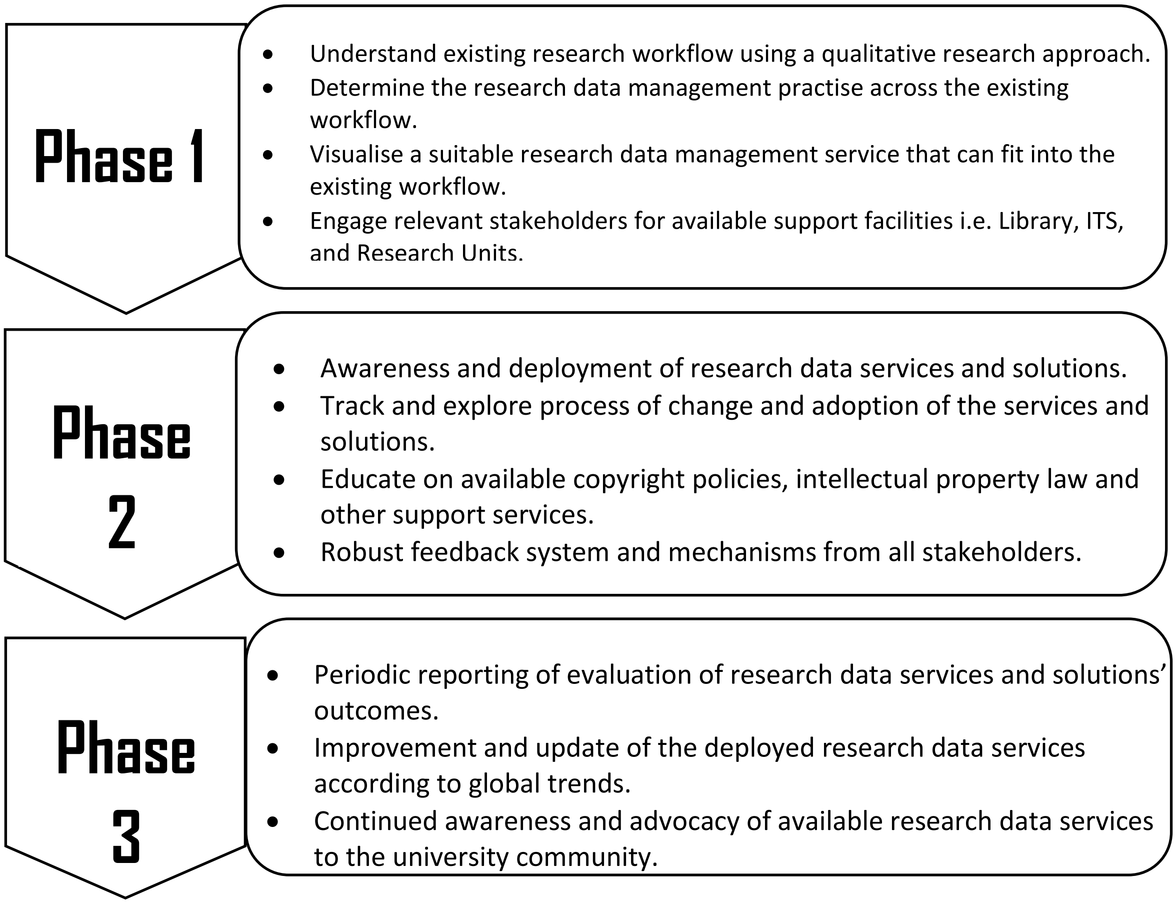


Figure 4.58:Proposed Framework for Incorporating Research Data Services by Libraries in FUTs in Nigeria

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study concludes that there is the need for libraries in FUTs in Nigeria to strive to achieve their research support objectives in their host universities. The need for research data management cannot be overemphasized as research data are increasingly being required to be submitted alongside articles for publication, one of the requirements for grant proposals, and a means of verifying and replicating researches in future. Awareness and practice of chemists in federal universities of technology in Nigeria on the importance of preserving and properly managing research data is low. The Chemists however opined that the awareness, advocacy and training should be from university library which they see as the safest and trusted storehouse of intellectual contents. They also requested for a data management system that can fit into their existing workflow with no disruptions, hence, the development of this study's computer-based data management model.The computer-based data management model was tested for acceptance among chemists in federal universities of technology in Nigeria and was accepted for continued use provided performance expectancy, effort expectancy, social influence, and facilitating conditions are properly kept in check and remain favourable.

5.2 Recommendations

The study recommended the following:

1. the libraries in federal universities of technology in Nigeria should roll out research data management services using the proposed framework suggested by this study;
2. the library and ITS unit should ensure the computer-based data management model developed by this study is available for use and that the necessary support is accessible at all times;
3. the university management should formulate and implement a policy that will encourage appropriate data management practice by researchers;
4. the library should intensify efforts on creating continued awareness, advocacy and training on research data management skills.

5.3 Suggestions for Further Study

1. The methodology used in this study can be adapted to understand research data management practise and perceptions of researchers in other fields like Humanities, Social Sciences, etc.and an appropriate solution suggested.

2. The framework suggested by this study can be applied in other conventional universities asides federal universities of technology in Nigeria and in other fields of study.

3. The ChRDMS can be updated into a mobile app for researchers to use in managing their research data.

5.4 Contributions to Knowledge

The study contributed the following to knowledge:

i. Conducted a study on research data management practice of chemists in FUTs Nigeria.

ii. Developed a domain specific computer-based data management model that is relevant to Nigerian research environment and workflow.

iii. Discovered the significance of research experience on effective research data management.

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APPENDIX A

INFORMED CONSENT FORM

I, the undersigned participant, confirm that (please tick box as appropriate):

1.	I have read and understood the information about the project, as provided in the Information Sheet dated ______________________________.	☐
2.	I have been given the opportunity to ask questions about the project and my participation.	☐
3.	I voluntarily agree to participate in the project.	☐
4.	I understand I can withdraw at any time without giving reasons and that I will not be penalised for withdrawing nor will I be questioned on why I have withdrawn.	☐
5.	The procedures regarding confidentiality have been clearly explained (e.g. use of names, pseudonyms, anonymization of data, etc.) to me.	☐
6.	I agree to the use of tape recorder for recording responses that will be used strictly for this research.	☐
7.	The use of the data in research, publications, sharing and archiving has been explained to me.	☐
8.	I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the data and if they agree to the terms I have specified in this form.	☐
9.	Select only <u>**one**</u> of the following: • I would like my name used and I understand what I have said or written as part of this study will be used in reports, publications and other research outputs so that anything I have contributed to this project can be recognised.	☐
	• I do not want my name used in this project.	☐
10.	I, along with the Researcher, agree to sign and date this informed consent form.	☐

Participant:

________________________ ________________ ________________

Name of Participant Signature Date

Researcher:

________________________ ________________ ________________

Name of Researcher Signature Date

APPENDIX B

INFORMATION SHEET

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY
DEPARTMENT OF LIBRARY AND INFORMATION TECHNOLOGY

My name is ABDULDAYAN Fatimah Jibril, a PhD student from the above named Department and School. I am carrying out a research on developing **"A Computer-Based Data Management Model for Chemistry Research in Federal Universities of Technology (FUTs) in Nigeria."**

Research data are valuable products of the scientific enterprise that historically have not been well preserved or archived. They are data collected, observed or created for the purposes of analysis to produce and validate original research results. International sponsors and scientific journals are now encouraging or requiring sound data management plan and data sharing before granting fund or accepting article for publication indicating how critical effective data management practices are to the scientific research processes. There is therefore, the need to develop a computer-based data management for researchers in Nigeria that will suit our peculiar research workflow and environment.

As part of requirements gathering for the development of the data management model, this interview schedule seek to determine the existing data management practices of Chemists in FUTs in Nigeria.

You have been selected as part of this study because:

i. You have a doctorate degree (PhD) or currently on doctoral training;
ii. You are within the rank of Professor – Lecturer II;
iii. You are involved in active research in Chemistry;
iv. You belong to one of the FUTs in Nigeria.

Your responses will be made confidential, as stated on the attached Informed Consent form, and used strictly for the purpose of this research.

Please feel free to respond to the questions and express yourself further, if necessary.

Thank you for your time.

ABDULDAYAN, F.J.
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APPENDIX C

INTERVIEW SCHEDULE FOR CHEMISTS IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

The researcher is interested in how you manage your research data including the processes, methods and tools used when working with data at each stage of the research.

In this section, the researcher is interested in knowing how you create and manage data and files, the techniques you have developed to organize, format and record the details of your research data.

1. What do you understand by the term 'data'?
2. What then do you understand by research data?
3. What are the various types of research data you know?
4. Do you generate digital data?
5. What are the different types of digital data generated? E.g. spreadsheets, texts, images, database, video, Matlab, scanned documents, NMR spectroscopy, etc.
6. Can you name some of the software used in digital data generation?
7. How do you name your stored data?
8. How do you manage different versions of research data generated during experiments?
9. How do you record details of research data e.g. name, source, date etc.
10. Have you experienced any situation where you have lost data due to poor file storage, unrecognized file format or bad storage device?
    a. Can you describe what happened?
    b. Did you find a solution? What did you learn from it?

In this section, the researcher is interested in knowing how you decide your storage needs and manage storage and back up.

1. How do you decide which storage media to use for your data files?
2. What factor do you consider in choosing a storage media for storing your research data?
3. Do you keep record of the media and location of files anywhere?
4. Are you aware of the advantages and disadvantages of different storage media?
5. How do you estimate size of research data?
    a. Is this easy to do?
6. Can you estimate the likely growth of files?
7. What media do you use for additional storage?
8. How do you protect or secure your research data?
9. Can you explain your back up methods?
    a. Do you record details of back up files? e.g. location, date of back up?
10. How would you describe a situation where had hardware or software failures and inability to access old files?
    a. What did you or would you do?

11. Would you like advice and guidance on data storage and back up?

In this section the researcher is interested in knowing how you share, transfer and ownership of data.

1. Would you be willing to share research data and with whom?
2. What data would you be willing to share? Raw or analysed data?
3. Have you heard of Open Access, Open Science, and Open Data?
   a. Do you support these principles?
4. Are you aware of any Intellectual Property Rights or copyright associated with research data?
5. When would you like to share your research data and with whom?
   a. After research before publication?
   b. After publication?

In this section, the researcher is interested in how you preserve and reuse your research data

1. What would you consider to be long term preservation – in years?
2. When considering preserving data for long term, how would you decide?
   a. What data to preserve long term?
   b. How long to preserve the data?
3. Where would you go for help in case of research data preservation and related problems?
4. Would you like additional advice and guidance on research data preservation or reuse?

In this section, the researcher is interested in the plans and policies which may influence your data management.

1. Are you aware of a Data Management Plan (DMP)?
   a. What is a data management plan?
2. What could motivate you to develop a data management plan?
3. What benefits of developing a data management plan are you aware of?
4. What are the possible challenges associated with developing a data management plan?

In this section, the researcher is interested in the advice and support you need to help you manage your data.

1. What types of advice and support do you think you need to manage your research data?
2. Where would you expect to find such advice and support?
3. Would you like a computer-based data management model to help manage your research data?
4. Do you envisage any problem with the computer-based data management model?
5. Please give any other information relevant to this study.

Thank you for your time!

APPENDIX D

INTERVIEW SCHEDULE FOR UNIVERSITY LIBRARIANS IN FEDERAL UNIVERSITIES OF TECHNOLOGY LIBRARY IN NIGERIA

The following questions seek to determine the awareness and support system expected from the university library on research data management. This will help the study to propose a framework for incorporating research data management services by libraries in FUTs in Nigeria.

SECTION A

Determining the Awareness of Research Data Management in the University Library.

1. Does the university library have an institutional repository (IR)?
2. Do you manage any digital repositories (or IR) where research data are stored?
3. Are you are aware of research data management?
4. Do you have any kind of research data submitted by researchers in your library or on the institutional repository?
5. Do you and/or librarians in your library have access to continuous professional development of librarian skills to cope with emerging trends in research data management and sharing?
6. Do you think librarians in your library can provide access to research data by means of standard metadata generation?
7. Are you aware of the Open Access, Open Science, and Open Data movements in scientific researches?
8. Does the university library have access to any open data repositories?

SECTION B

Determining the Support System expected from the Library on Research Data Management.

6. Does the university library have Intellectual Property Rights policy guiding the use of institutional repository?
7. Do you provide advocacy to researchers on the importance of submitting research data and related publications to the institutional repositories?
8. Do you consider poor attitude of researchers towards submission of research data to the library as a possible challenge to research data management?
9. Do you think librarians will require additional training on metadata generation from research data?
10. Do you think seminar and workshops on the importance of research data management will help to promote submission and management of research data in the university?
11. What are your suggestions on effective research data management by the library?

Thank you for your time!

APPENDIX E

INTERVIEW SCHEDULE FOR DIRECTORS OF INFORMATION AND COMMUNICATION (ICT) UNITS IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

The following questions seek to determine the awareness and support system expected from the ICT Unit on research data management. This will help the study to propose a framework for incorporating research data management services in FUTs in Nigeria.

1. Kindly give an overview of functions of the ICT Unit.
2. What are the available ICT support for researchers?
3. How would you describe the relationship between the University Library and the ICT Unit?
   a. In what capacity do you collaborate with the University Library?
4. Do you manage any Institutional Repository (IR) for your university?
   a. If none, what are the possibilities of having an IR?
5. Does the Unit have adequate storage space for research data?
6. Can the Unit assure the safety and security of research data stored on the repository?
7. What could be the likely challenges to effective research data management?
8. What suggestions can you give for successful implementation of Research Data Management in your university?

Thank you for your time!

APPENDIX F

INTERVIEW SCHEDULE FOR DIRECTORS OF RESEARCH UNITS IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

The following questions seek to determine the awareness and support system expected from the research office on research data management. This will help the study to propose a framework for incorporating research data management services in FUTs in Nigeria.

1. Kindly give an overview of functions of the Research Unit of your University.

2. What do you consider as research best practice?

2. What are the available research grants (local and International) in your university?

3. Are researchers in your university winning such grants and awards? Kindly provide statistics on grants available and won.

4. Are you aware of research data and data management plan (DMP)?

5. What is the position of a data management plan in applying for grants or funding?

6. Are there any support system for researchers on proposal writing and developing a good data management plan?

7. In what areas can researchers be best assisted in ensuring better conduct of researches?

8. Is there any policy in support of research data management?

    a. If none, would your university be willing to develop policy supporting research data management?

9. What suggestions can you give for successful implementation of Research Data Management in your university?

Thank you for your time.

APPENDIX G

OBSERVATION CHECKLIST OF CHEMISTRY LABORATORY EQUIPMENT IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

S/No	Laboratory Equipment	Available and Functional	Available Not Functional	Not Available
1.	Safety goggles and safety equipment			
2.	Beakers			
3.	Erlenmeyer flasks AKA conical flasks			
4.	Florence flasks AKA boiling flasks			
5.	Test tubes tongs and racks			
6.	Watch glasses			
7.	Crucibles			
8.	Funnels			
9.	Graduated cylinders			
10.	Volumetric flasks			
11.	Droppers			
12.	Pipettes			
13.	Burets			
14.	Ring stands rings and clamps			
15.	Tongs and forceps			
16.	Spatulas and scoopulas			
17.	Thermometers			
15.	Bunsen Burners			
16.	Balances			
17.	Fourier Transform Infrared (FTIR) Spectrometer			
18.	High Resolution Scanning Electronic Microscope (HRSEM/EDX)			
19.	Thermo gravimetric analysis (TGA)			
20.	Raman Spectroscopy			
21.	X-Ray Diffraction (XRD)			
22.	Brunauer–Emmett–Teller (BET)			

APPENDIX H

OBSERVATION CHECKLIST OF UNIVERSITY LIBRARIES IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

S/No	Tools/Resources/Services in University Library	Available and Functional	Available Not Functional	Not Available
1.	Electronic Databases			
2.	Institutional Repository and content			
3.	Electronic Services			
4.	Types of Digital Collections			
5.	Format of Digital Collections			
6.	Preservation methods			
7.	Intellectual Property Right			

APPENDIX I

OBSERVATION CHECKLIST OF INFORMATION AND COMMUNICATION TECHNOLOGY UNITS IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

S/No	ICT Tools/Equipment in ICT Unit	Available and Functional	Available Not Functional	Not Available
1.	Computer Workstations			
2.	Servers			
3.	Alternative Power Supply (e.g. Solar Farms)			
4.	Software			
5.	Firewalls			
6.	Data Security			
7.	Staffing			

APPENDIX J

QUESTIONNAIRE FOR CHEMISTS IN FEDERAL UNIVERSITIES OF TECHNOLOGY IN NIGERIA

The questions below is aimed at determining your behavioural intention to accept and use the developed data management prototype. Kindly tick as appropriate. Thank you.

Gender: Male ( ) Female ( )

Age: 25-35years ( ) 36-45years ( ) 46-55years ( ) 55years & above ( )

Years of work experience: 5-10years ( ) 11-15years ( ) 16-20years ( ) 20years & above ( )

Years of research experience: please state the number(s) of article published in the years stated below:

i. I have published ________________article (s) within the year (2014-2019)
ii. I have supervised _________________students projects, theses and dissertations within the year (2014-2019)
iii. I have _________________ conference paper presentations within the year (2014-2019)
iv. I have _________________ book publications within the year (2014-2019)
v.
vi. I have published__________________ article (s) within the (2014-2019)
vii. I have _________________ patented research findings.

After your initial use of the developed data management prototype, kindly tick the options that may influence your behavioural intention to continued use of the model:

Scales / Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Performance Expectancy (PE)					
PE1: I find the prototype useful to my research workflow.					
PE2: Using the prototype enables me to manage research data more quickly.					
PE3: Using the prototype increases my research productivity.					
PE4: Using the prototype increases my chances of publishing in impact factor journals.					
Effort Expectancy (EE)					
EE1: My interaction with the prototype is clear and					

understandable.					
EE2: It is easy for me to become skillful at using the prototype.					
EE3: I find the prototype easy to use.					
EE4: Learning to operate the prototype is easy for me.					
Social Influence (SI)					
SI1: People who influence my behaviour think that I should use the prototype.					
SI2: People who are important to me think that I should use the prototype.					
SI3: Library will be helpful in the use of the prototype.					
SI4: In general, the university will support use of the prototype.					
Facilitating Conditions (FC)					
FC1: I have the resources necessary to use the prototype.					
FC2: I have the knowledge necessary to use the prototype.					
FC3: The prototype is compatible with other systems I use.					
FC4: A specific person (or group) is available for assistance with the prototype challenges					
Behavioural Intention to Use the System (BI)					
BI1: I intend to use the prototype in my subsequent researches.					
BI2: I predict I would use the prototype in my subsequent researches.					
BI3: I plan to use the prototype in my subsequent researches.					
Actual Use of Technology (AT)					
AT1: Using the prototype is a good idea.					
AT2: The prototype makes research more interesting.					
AT3: Using the prototype to manage my research data is fun.					
AT4: I like using the prototype for my data management plan (DMP)					

APPENDIX K

CRONBACH'S ALPHA RELIABILITY TESTING

Scale: Actual Use of Technology (AT)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.737	4

Scale: Behavioural Intention to Use the System (BI)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.944	3

Scale: Facilitating Conditions (FC)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.820	4

Scale: Social Influence (SI)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.831	4

Scale: Effort Expectancy (EE)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.683	4

Scale: Performance Expectancy (PE)

Case Processing Summary

		N	%
Cases	Valid	17	73.9
	Excluded[a]	6	26.1
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.740	4

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
19.0588	4.184	2.04544	4

Average of Cronbach's alpha value:

$$\frac{0.74 + 0.68 + 0.83 + 0.82 + 0.94 + 0.74}{6} = 0.79$$

0.74+0.68+0.83+0.82+0.94+0.74= 4.75/6

= 0.79

APPENDIX L

LIST OF PUBLICATIONS SO FAR

Abduldayan, F.J., Abifarin, F.P., Oyedum, G.U. and Alhassan, J.A. (2021), "Research data management practices of chemistry researchers in federal universities of technology in Nigeria", *Digital Library Perspectives*, Vol. 37 No. 1, pp. 70-90. https://doi.org/10.1108/DLP-06-2020-0051

Abduldayan, F. J., Abifarin, F. P., Oyedum, G. U., & Alhassan, J. A. (2021).Users' acceptance testing of a computer-based research data management system in federal universities of technology in Nigeria. A paper presented at the 2nd International Conference on ICT for National Development and Sustainability (ICT4NDS2021), Faculty of Communication and Information Sciences, University of Ilorin, March 3-5, 2021.

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APPENDIX U
SORTED DATA POINTS FOR FUTS IN NIGERIA

DATA POINTS	RANK
29	2
29	2
29	2
30	4
31	5
32	6.5
32	6.5
33	11
33	11
33	11
33	11
33	11
33	11
33	11
34	15.5
34	15.5
35	18
35	18
35	18
36	21.5
36	21.5
36	21.5
36	21.5
37	26
37	26
37	26
37	26
37	26

38	29
39	31
39	31
39	31
40	33
40	35.5
40	35.5
40	35.5
40	35.5
40	35.5
42	39.5
42	39.5
43	44
43	44
43	44
43	44
43	44
43	44
43	44
44	49
44	49
44	49
45	51
46	53
46	53
46	53
47	56.5
47	56.5
47	56.5
47	56.5
48	59.5

48	59.5
49	61.5
49	61.5
50	64
50	64
50	64
51	67
51	67
51	67
52	70.5
52	70.5
52	70.5
52	70.5
53	73
54	75
54	75
54	75
55	77.5
55	77.5
56	79.5
56	79.5
57	82
57	82
57	82
58	84.5
58	84.5
59	87.5
59	87.5
59	87.5
59	87.5
60	91.5

60	91.5
60	91.5
60	91.5
61	94.5
61	94.5
62	96
63	97.5
63	97.5
64	99
65	100.5
65	100.5
68	102
69	103
70	104.5
70	104.5
72	106
74	107
76	108.5
76	108.5
78	110
79	111.5
79	111.5
84	113
87	114
88	115