MASTER THESIS

IMPLEMENTATION OF ICT INFRASTRUCTURE IN HIGH SCHOOLS OF RURAL & REMOTE REGIONS

GAYATHRI SARALAYA

SUPERVISORS:

PROF. DR. M. E. IACOB

DR. M. DANEVA

UNIVERSITY OF TWENTE.

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Author:

Gayathri Saralaya

Master of Business Information Technology

University of Twente

Graduation Committee:

University of Twente

First Supervisor: Prof. Dr. Maria-Eugenia Iacob

Second Supervisor: Dr. Maya Daneva

Preface

With a bachelor's degree in computer science and growing up in a business environment, I was curious about the business side of IT and hence decided to pursue my Master's in Business Information Technology. From moving away from home to an unknown country and learning with peers from all around the world, each day has been an experience in itself.

Coming from a family that believes in giving back to the society, rural education is something that was interesting to me. Certain news channels that showed the struggle of these students to access basic ICT infrastructure like internet during times of Covid-19 pandemic, made me eager to pursue this topic for my Master thesis.

This has been a long journey and this document marks the end of this journey. This endeavour would not have been possible without the extensive support of all the people who were a part of it in one or the other way. I also know that they will always keep supporting me for every new thing I decide to take up in my life.

I would like to thank my supervisors prof. dr. Maria Iacob and dr. Maya Daneva for their patience and guidance. Their insights and knowledge on the topic and proactively providing the necessary resources for my thesis play an important part in the completion of my thesis. I would also like to thank Iqbal Mukti for his guidance which helped me understand and analyse my thesis.

This journey would not be possible without the guidance and support of my parents Mr. Prabhakar Saralaya and Mrs. Malathi Saralaya. I would also like thank all my other family members and friends, with special thanks to Akshay Puned, for being there when I needed them the most. I express my gratitude to all the people who filled out the required surveys and forms and helped me successfully complete this thesis.

Last but not the least, my sincere gratitude to the University of Twente for giving me this opportunity to experience learning at such an esteemed institute from where I take away knowledge and experiences that will stay with me throughout my life.

Gayathri Saralaya

Enschede

Abstract

Empirical research studies reveal that a vast majority of the youth population of rural and remote regions of developing countries lack the necessary skills and knowledge to use basic Information and Communication Technology (ICT). It is important to imbibe such knowledge and prepare the young minds for the rapidly progressing world that demands encounters with high end technologies in day-to-day lives. The most methodical way to do this is to introduce the concept of digital smartness at high school level, by incorporating ICT seamlessly into the schools' educational processes. However, it is difficult to do so due to the lack of adequate ICT infrastructure. This is mainly due to the geographic and economic conditions of these regions. Therefore, there is a need to assess the current state of the educational institutions in order to provide a solution for adoption of ICT infrastructure for educational purposes. Accordingly, the main aim of this thesis is to propose a reference IT architecture that will facilitate the implementation of Smart Education in the context of rural and remote regions.

The development of the reference architecture is done in four stages. The first stage is a systematic literature review which represents the state-of-the-art for ICT implementation in context of rural and remote regions. The final results of this stage give an overview on the (i) challenges, (ii) available solutions and (iii) requirements for implementing ICT in rural and remote regions present in current literature.

The second stage of this thesis uses an empirical research method to identify factors that influence the adoption of Smart Education in rural and remote regions. In this stage the results of the literature review are classified into Technological, Organizational and Environmental factors. Based on the principles of rural smartness and the T-O-E framework a theoretical model for predicting the adoption of Smart Education is drawn. Following the empirical research method seven hypotheses are formulated for the variables of the theoretical model. These hypotheses are then quantitatively evaluated using surveys with practitioners working in the related field, teachers of rural and remote educational institution for this thesis. Statistical analysis using PLS-PM is performed on the gathered data. The final results of this stage are (i) the theoretical model for predicting the adoption of smart education (ii) the findings of the analysis that help in confirming or falsifying the hypotheses and (iii) the variables and indicators which are the factors that influence the adoption of smart education in rural and remote regions.

The third stage of this thesis uses Wieringa's design science cycle to develop an artefact which is the reference IT architecture for ICT infrastructure implementation in rural and remote regions. The problem investigation for this design science cycle is carried out in the earlier stages of this thesis. Therefore, the variables of the theoretical model have been translated into functional requirements of the architecture. This stage focuses on the treatment design which uses ArchiMate modelling language to realize theoretical models into architectural models. The architecture model incorporates all the relevant aspects across all business units and models them into individual viewpoints. The final results of this stage are the seven viewpoints which are (i) Motivational Viewpoint, (ii) ICT Infrastructure Viewpoint, (iii) Application Interface Viewpoint, (iv) Organizational Readiness Viewpoint, (v) Training Viewpoint, (vi) Third Party Collaboration Viewpoint and (vii) Final architecture Viewpoint.

The final stage of this thesis is the final phase of the design science cycle which is treatment evaluation. Goodness, completeness and usefulness of the reference architecture designed earlier are evaluated in two stages. First a group of experts who are familiar with the problem context and the concept of ICT infrastructure were interviewed to check the goodness and completeness of the artefact. In the perception of the involved interviewees, the reference architecture is found to be well designed, well developed and easy to understand. The reference architecture is also considered practical for implementation by the experts. Second, teachers of rural and remote educational institutions evaluated usefulness of the reference architecture by answering questions formulated using the UTAUT model. In this second evaluation stage the UTAUT questionnaire focused on the performance expectancy, effort expectancy, social influence and facilitating conditions for the reference IT architecture. The findings of the UTAUT evaluation indicate that the overall results are positive and therefore provide evidence that the reference architecture is useful, and the smart education system is compatible with all aspects of teaching and learning process.

The final results of each stage in this thesis are the individual elements which make up the two main contributions. These are: (i) The theoretical model for predicting the adoption of Smart Education and (ii) The IT reference architecture for implementing Smart Education. This thesis and its contributions are strengthened by the combination of two well established research methodologies, the empirical research method and Wieringa's design science cycle. The methods used for evaluating the artefact, expert interviews and UTAUT questionnaire, also add significant value to the scientific contribution of this thesis. The evaluation of the artefact itself also provides substantial evidence that the architecture has addressed the requirements for which it was designed.

Keywords: ICT Infrastructure, Rural and Remote Regions, High Schools, IT Architecture, Reference Architecture, ArchiMate

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1. Introduction

Right to education has been recognized as a human right by many international conventions. This includes the obligation to develop equitable access to higher education. Higher education should also involve the use of Information and Communication Technology (ICT). This means computers, internet, multimedia and educational software and even online education during times of need should be part of the teaching and learning process. However, not every child living in the rural and remote areas gets access to this type of educational practices. The economic constraints of governments to provide free basic education and the low socio-economic status of parents are serious barriers preventing children from receiving a high standard of education and experiencing quality of life (du Plessis & Mestry, 2019). The lack of ICT also acts as a barrier for teachers to provide the students with the best quality of education due to which students are withheld the access to new technological advances happening in the world.

Computers and communication technology together have developed so much in the recent years that they could improve the quality of education (Bailey & Cotlar, 1994). This shows that access to online educational content is a potential solution that could help not only the students to learn and have reference materials that could be used for assignments and examinations, but also teachers to enrich their lesson plans. By giving access to valuable and affordable practical resources and trainings to young people, new potentials will open for them. Initiating education improvement programs in schools, to prepare students with digital skills of the current era is a necessity. Access to online education will be a huge step in the direction of higher quality education. Hence it is important to start working towards providing IT-Infrastructure and educational software to high schools of such rural and remote regions.

Another viewpoint for the same problem is that many people living the rural regions tend to move towards the urban regions in search of employment opportunities. Due to lack of technological skills they end up in minimum wage jobs or remain unemployed (Zhang, 2016). This leads to poverty and an income gap. A quality education with basic ICT skills will help them land better jobs and lower the income gap.

There is a need for including ICT in schools and hence a need for better IT infrastructure in rural regions. This can be done by introducing the concept of “Smartness” in these regions. The concept of Smartness is associated with including ICT to enhance the efficiency of the city in all terms (Husár, Ondrejička, & Varış, 2017). Therefore, it is important to extend this concept of Smartness into rural and remote areas to improve their efficiency as well. This will help not only improve the lives of people migrating to urban cities find better jobs but also create a better economic condition for the people living there.

To provide access to ICT and online educational provisions several factors must be considered. Such as their hardware and software components, the availability of servers that can withstand extreme temperatures of a specific region, internet, bandwidth, software packages, technology support etc. (Muirhead, 2000). As a result of rural areas being remote and poorly developed, they lack many physical resources and basic infrastructure such as electricity, information, communication technology (du Plessis & Mestry, 2019) and many other small yet important resources. The lack of these resources also makes it difficult to have internet facilities in these schools to enable online educational facilities. Therefore, it is important to address the infrastructural problems to provide ICT involved learning facilities for high schools of such regions. The fact that there is already lack of economic support, financial constraints should also be considered. The requirements to implement ICT and online learning facilities in remote and rural regions need to be systematically listed. An IT-architectural model will be an effective tool for reviewing the current state and providing a future plan for such problems (Tamm, Seddon, Shanks, & Reynolds, 2011). An added advantage of using an IT architecture is that the physical details as well as other elements that aid the implementation of ICT can be easily represented on the architecture, which makes the process of understanding and adopting much easier than traditional methodologies where it is only written what is to be done and not how it is to be done.

1.1 Research Goal

Technology facilitates people in remote and rural regions to have access to lighting, communication as well as a variety of educational opportunities by reducing illiteracy and improving the quality of education (Diniz, Franca, Camara, Morais, & Vilhena, 2006). The concept of extending Smartness to rural regions has already started gaining attention and there exist a few frameworks, models, strategies, methodologies to do the same which can be seen in the Systematic Literature Review (SLR) chapter. There is a need for a model that aids in providing a clear picture of the required facilities that improve the quality of education in these regions. An architectural model that would elaborate and guide the adoption of ICT and implementation of ICT in rural regions is needed. There is also a need for empirical assessment of the model so that it is easier to be applied to a real case scenario.

Therefore, the research goal here is:

> ***To propose a reference IT architecture to facilitate implementation of Smart Education in context of rural and remote regions.***

To reach this goal, the present research will employ a research process that includes various steps. Initially a systematic literature review to find the state-of-the-art for implementing ICT infrastructure in the context of rural and remote education is conducted. This step yields the challenges, available solutions and requirements mentioned in existing literature on the problem context. The next step is to classify the findings into Technological, Organizational and Environmental factors. This step uses the empirical research method to formulate the theoretical model to find factors that influence the adoption of Smart Education. These factors are quantitatively validated using Partial Least Squares Path Modelling (PLS-PM). The final step uses the design science cycle to design an artefact for the problem context defined i.e., the reference IT architecture. This is then evaluated qualitatively using semi-structured interviews with experts and UTAUT model questionnaire.

1.2 Research Question

The aim of this research project is to identify and address the following research questions related to the field of ICT for education in rural regions with an aim of developing an IT architecture for facilitating ICT adoption in high schools in rural and remote regions. Based on this goal, this thesis is set out to answer the following central research question (RQ).

Main RQ:

- In what way can we facilitate the adoption and implementation of Smart Education in high schools of remote and rural areas?

This central RQ is decomposed into the following sub research questions:

RQ1. What is the state-of-the-art for ICT implementation in high schools of remote and rural areas?

RQ2. What are the factors that influence the adoption of Smart Education in high schools of remote and rural areas?

RQ3. What is the reference IT architecture for implementing Smart Education in remote and rural areas?

RQ4. Does the architecture serve its purpose? Is it good and useful?

Following R.Wieringa's classification of questions used in scientific research (Wieringa, 2014), RQ1 is considered a knowledge question, which is answered by using secondary sources such as journals and articles by other authors. Therefore, a systematic literature review is conducted to answer RQ1. RQ2 is an empirical question which will be answered by empirical research method. This empirical research method leads to the first contribution of this thesis which is the theoretical model for predicting the adoption of smart education. RQ3 is a design science question which produces the model as an artifact for the problem context defined. RQ4 is an evaluation question which will be evaluated using semi-structured interviews and UTAUT questionnaires. RQ3 and RQ4 lead to the second contribution of this thesis which is the artefact of reference IT architecture for implementing smart education. Chapter 2 describes the Design science methodology used in this research in a detailed manner.

1.3 Research Scope

The scope of this research is to design and evaluate a reference IT architecture that can be used to facilitate the implementation of ICT infrastructure in high schools of remote and rural regions for the purpose of smart education. In general, the area of smart education itself involves participation from many stakeholders who are associated with various processes and the associated (infrastructural) services provision activities. It also includes policy and strategy planning from the stakeholder that is the government. This also involves numerous activities and initiatives etc. To form the scope for this Master Thesis the following processes and stakeholders are considered. The processes include the teaching and learning process, the training process to train the users on using ICT, the support process, registration and enrolment process, implementation of policies and strategies and monitoring and maintenance process. The stakeholders included in this study are the end users of the system i.e., teachers, students, management and educational administrators of the educational institute, the government and the third parties who are the service providers, Non-Governmental Organizations (NGO), other universities and companies or industries.

1.4 Definitions

This section introduces the most important definitions that are relevant for the research in this thesis. These refer to the themes of ICT in education and Enterprise Architecture (EA). The sections that follow are focused on these themes.

1.4.1 ICT in Education

It is known that ICT stands for Information and Communication Technology, but it is important to define what it means in context of school and higher education. Although ICT is used in all fields of study, its primary definition revolves around the devices and infrastructures that facilitate the transfer of information through digital means (Zuppo, 2012). ICT is also defined as any technology that supports information gathering, processing, distribution and use (Beckinsale & Ram, 2006). It is important to associate ICT and schools while defining the term. Some literature reviews also see ICT as a tool to support and enhance the school learners' interest and motivation (Laferrière, Breuleux, & Bracewell, 1999). Literacy in ICT is defined as "the interest, attitude and ability of individuals to appropriately use digital technology and communication tools to access, manage, integrate and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in society" (Kim, Kil, & Shin, 2014). ICT is defined as an umbrella term that includes any communication device or application encompassing computer, network hardware, software and so on and the services and applications associated with them such as distance learning etc (Ramirez, Collazos, & Moreira, 2018). Therefore, ICT in education refers to collection, processing, and transfer of information necessary that supports education and learning through the means of digital devices along with applications and services that support the same.

1.4.2 IT Infrastructure

Firstly, infrastructure is mentioned as the core of general functionality upon which other applications can be built (DiLauro, 2004). It is a resource and capability that enables information sharing through interaction of technology and people in the organization who share different elements.

An IT-infrastructure consists of Hardware and operating software, communications, and other components. It can also be defined as a set of shared IT resources which is a foundation for communication across the organization (Chanopas, Krairit, & Khang, 2006) where technical infrastructure consists of hardware, software, the network, telecommunications, applications, and tangible IT resources. IT-infrastructure can also be defined as the combination of hardware, software, people, procedure, and data that support the information flow in an organization (Shaw, 1999).

The dimensions of IT-infrastructure can also be specified. According to Keen (1991) , Reach and Range are the two dimensions. Reach is the defined as the locations to which the infrastructures can be linked and range is the breadth of information that can be directly shared among the components of a particular infrastructure (Weill, 1993).

Therefore, for the purpose of this study IT-infrastructure can be defined as a combination of hardware, software and application components that aid in information storage and processing, along with integrated components such as the internet that help in flow of information in reach and range of educational purposes.

1.4.3 Enterprise Architecture

There are numerous definitions in literature for enterprise architecture. Enterprise Architecture is defined as a technology and management practice that helps to improve the performance of an enterprise by providing a holistic and integrated view of the strategic directions, business processes, information flow and technology resources (Bernard, 2012). It is also defined as a framework for how an organization defines it current and future business objectives by examining its key business, application, technology and strategy and impact of these components on business functions (Pereira & Sousa, 2004). Based on the two definitions enterprise architecture is a view that represents all the components of an enterprise in terms of management and technology and assesses their impact on the business functions to define new strategies for the future. The management components include details of business processes, strategic decisions etc. The technological components include details of infrastructure, devices, information flow.

1.4.4 ArchiMate

Archi, which is a modelling tool is used to design and represent the elements of the final reference IT architecture. Archi is a tool which supports the ArchiMate modelling language. ArchiMate is a language that allows enterprise architecture concepts to be described, visualized and analysed in an unambiguous way. It provides a graphical language for representation of models/architectures (Josey, Lankhorst, Band, Jonkers, & Quartel, 2016). The six layers of representations that are possible on ArchiMate are:

1. *Strategy*: The strategic decisions, the business plans, etc. where the high-level strategies on paper can be modelled with strategy elements.
2. *Business*: The business services, business processes, business functions can be realized with business products and service elements.
3. *Application*: Application services are realized with application components.
4. *Technology*: All the infrastructures represented on paper can be modelled using the technological components. This usually consist of applications, software, middleware etc.

5. *Physical*: Physical devices, hardware, etc are modelled with physical elements.
6. *Implementation and migration*: These concepts support the modelling of migration plans, portfolio management etc.

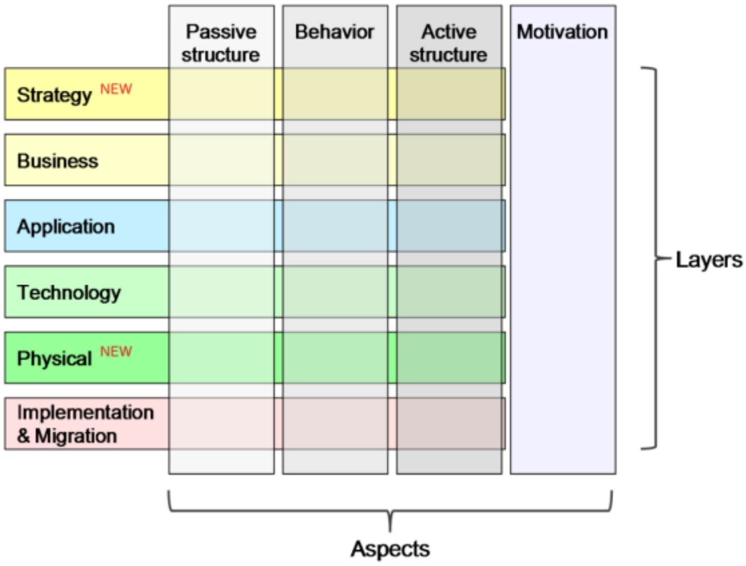

Figure 1: Layers & Aspects of ArchiMate

The six layers make up the ArchiMate Framework and the basic template of the framework is shown in Figure 1. The layers consist of four aspects: Passive structure, Active structure Behaviour and Motivation. The motivation aspect is the most recent addition to the group which reasons the choices behind any decision undertaken.

2. Research methodology

The research methodologies that are used as guidelines for this research is described here. There are three different types of research questions that are addressed in this thesis. RQ1 is considered a knowledge question. RQ2 is an empirical question, and RQ3 and RQ4 are design science questions. For the empirical question we test the viability of the question by empirical evidence that is by validating the hypotheses using quantitative validation by means of surveys. For the design science question, the design science cycle is used as reference. These two approaches, i.e., the empirical research method and design science cycle were selected as research methods for this thesis as it fits best with the goals of this research and the process aligns with the process steps in the artifact design. This section elaborates on the two research methods and their application in this thesis.

2.1 Empirical Research Method for developing the theoretical model

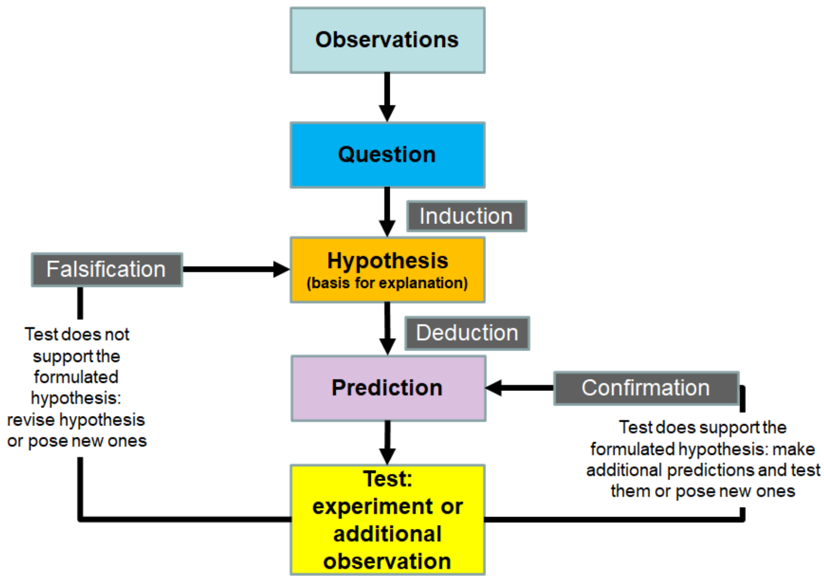

Figure 2: Empirical Research Method

To answer the sub-research question RQ2, empirical research method is used. This method is represented in Figure 2. This question is addressing the development of the theoretical model for predicting the adoption of smart education. The theoretical model defines certain variables and their indicators that influence the adoption of smart education in rural and remote regions. Empirical research method is used to observe how and to what extent these variables and indicators influence each other and smart education itself by formulating seven hypotheses. The empirical research method entails gathering of data to test the correctness of the hypothesis formulated. This is then followed by induction or deduction. Inductive approach collects the data and then tests it against theory that is being developed. Deduction approach initially formulates the hypothesis, assuming the theory and then tests it against the gathered data. The final test can be either falsified or confirmed based on the outcome of the test. This is seen diagrammatically on the following Figure.

For this research, the deduction approach is being followed. The primary data required to formulate the research question is gathered with the help of the literature review conducted. The research question (RQ2) is answered by assuming that the observations from the literature review are correct. Hypothesis is formulated for the same assumption. This is then tested on a small population, that fits the context of this research. The means of testing would be surveys that would be sent to the target population. The data gathered through these surveys is then analysed using structural equational modelling and the correctness of the formulated hypothesis is verified.

2.2 Design Science Cycle to develop the IT Artefact

The development of the IT artefact uses the guidelines provided by the design science cycle. The engineering cycle is a process of solving problems rationally which is represented in Figure 3. It consists of five tasks which are problem investigation, treatment design, treatment validation, treatment implementation and implementation evaluation (Wieringa, 2014). For the purpose of this thesis only the design cycle which is a part of the engineering cycle is used. This thesis does not focus on the implementation of the artefact hence the design science cycle for this thesis focuses on mainly three tasks: problem investigation, treatment design and treatment validation. The problem investigation task is associated with answering what problem should be addressed and why. Treatment design is the task where an artifact is produced that would solve the earlier defined problem. Treatment validation deals with checking if the artifact would solve the problem that was earlier defined.

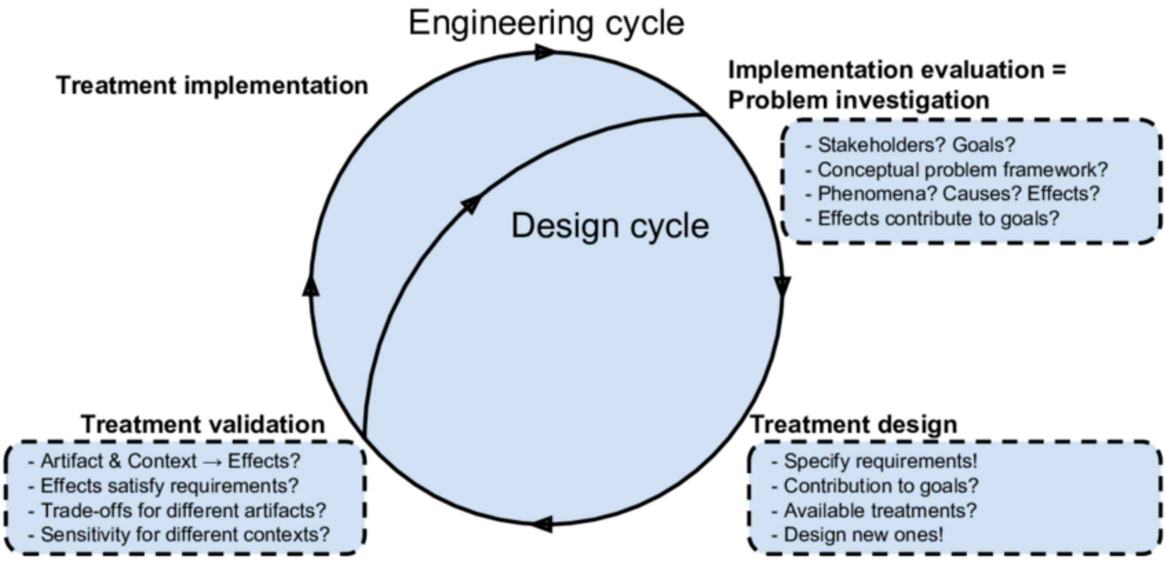

Figure 3: The Design Science Cycle (Wieringa, 2014)

2.3 Thesis Structure

This research study is conducted following the guidelines of design science and empirical research method as mentioned in the previous chapter. This means using a number of research techniques, which are literature survey, empirical research and design-based research for producing an artifact that addresses a problem identified earlier. This thesis is structured as follows; Chapter 1 refers to the problem identification part of the design cycle where the context is produced and the need for an artifact is mentioned. Chapter 1 also identifies the objectives of the undertaken research project with the help of the research and sub-research questions designed. Chapter 2 deals with the methodology in which the research is conducted. Chapter 3 answers RQ1 through a systematic literature study conducted. This helps to get to the state-of-the-art that helps in defining the requirements and designing the artifact. Chapter 4 and chapter 5 together use the empirical research method to formulate and validate hypotheses that provide evidence for factors that influence the adoption of smart education. Chapter 4 focuses on designing the theoretical model for predicting the adoption of smart education by defining the variables and indicators that form the model. Chapter 5 focuses on validation of the model by means of survey questionnaires. This chapter empirically validates the theoretical model by means of statistical analysis. The design-based research is seen in Chapter 6 and Chapter 7 which focus on developing and designing the artefact. Chapter 6 represents the reference IT architecture, which is the artefact itself. It consists of the various viewpoints that align with the different aspects of implementing ICT infrastructure in rural and remote regions. Chapter 7 provides a qualitative evaluation of the architecture designed in Chapter 6 referring to the treatment evaluation phase of the design-science cycle. Chapter 8 discusses the reflection on the entire research followed by the conclusions and limitations of this research in Chapter 9.

3. State-of-the-art for ICT Implementation in High Schools of Rural and Remote Areas

The current state-of-the-art for implementing IT in remote and rural regions is described in this chapter. This addresses the main challenges, available solutions and also the requirements for implementation from already available literature. This is done using a systematic literature review as mentioned earlier. The subsections of this chapter include the methodology used for conducting the SLR, planning, selection and extraction of data and finally the results are analysed for the conclusion of this chapter.

The SLR methodology of (Kitchenham & Charters, 2007) in the domain of software engineering is used. This method has three phases: design, conducting and reporting. An explanation of the phases is shown in Table 1 and the detailed explanation will be given in the following sub-sections.

Table 1: SLR Activities

3.1	Planning
3.1.1	Defining the Research Questions and the sub-questions
3.1.2	Selecting the Database for Search Process
3.1.3	Formulating the Search Query
3.1.4	Defining the inclusion and exclusion criteria
3.2	Selection
3.2.1	Data Extraction
3.3	Result Analysis & Discussion

3.1 Planning

Planning phase focuses on defining the objectives of this literature study such as the research questions, selecting the databases to gather data for the study, formulating the search query using the specific keywords and defining the inclusion and exclusion criteria to obtain the results.

3.1.1 SLR Research Questions

Research questions consists of keywords that help in formulating the search query which helps in determining the search process, data collection and data synthesis. The aim of this literature study is to identify and address the following research questions related to the field ICT for education in remote and rural regions.

Main RQ for SLR:

What is the state-of-the-art in IT Infrastructure for high schools in rural and remote areas of developing countries?

Sub-RQ for SLR:

1. What are the challenges for implementing IT architecture in high schools of rural and remote regions?

2. What are the available solutions for implementing IT architecture in high schools of rural and remote regions?

3. What are the requirements for the adoption of IT solutions in rural and remote areas?

3.1.2 Scientific Databases

This SLR focuses on the use of scientific databases for the purpose of data collection. Although there are many databases available, two well-known databases will be used for this study. This study focuses on the articles obtained from the following databases:

-Scopus (https://www.scopus.com)

-IEEE (https://ieeexplore.ieee.org)

The main reason to choose these databases is that they provide cutting-edge research articles and up-to date content. Also, most of the journals are multidisciplinary and easily accessible.

3.1.3 Search Query Formulation

The keywords that help in answering the questions are picked from the main RQ and the sub-RQs for SLR. This is represented in Table 2. Words that are synonymous to the keywords are also used in the search query as this would help in obtaining a larger dataset. For example, the word "Architecture" used in the search query answers the first sub-question, which further helps to answer the main question by obtaining different architectures that are currently being used.

Table 2: Keywords

IT	Infrastructure	Architecture	Secondary education	Rural	Implementing
ICT	Infrastructures	Architectures	High school	Rural	Implement
Information Technology	ICT Infrastructure	Design	Senior School	Remote	Implementation
IT Framework	ICT Infrastructures	Pattern	Secondary High School	Village	Apply

Information Technology Framework		Reference	Secondary School	Isolated	Execute
Information Systems		Enterprise Architecture	Education	Developing Countries	Application
Educational Technology		Reference Architecture		Developing country	ICT Implementation
				Emergent nations	Adoption
					Acquiring
					Acquisition
					Acceptance

These synonyms of each keyword are grouped by using the “OR” operator and each keyword is clustered using the “AND” operator to form the final query. The query is used to find relevance in each article’s title, abstract and keywords. The final search query for each specific database is as follows:

Scopus (advanced search):

TITLE-ABS-KEY (("Information Technology" OR “IT Framework" OR "Information Technology Framework" OR "Information Systems" OR "Educational Technology" OR "ICT")

AND

("Infrastructure” OR "Infrastructures" OR “ICT Infrastructure” OR “ICT Infrastructures”)

AND

("Architecture" OR "Architectures" OR "Design" OR "Pattern" OR "Reference" OR "Enterpris e Architecture" OR "Reference Architecture")

AND

("Education" OR "School" OR "Secondary Education" OR "High School" OR "Senior School" OR "Secondary School" OR "Senior High School")

AND

("Rural" OR "Remote" OR "Village" OR "Isolated" OR "Developing Countries" OR "Developing country" OR "Emergent nations")

AND

("Implementing" OR "Implement" OR "Implementation" OR "Apply" OR "Execute" OR "Appli cation" OR "ICT
Implementation" OR "Adoption" OR "Acquiring" OR "acquisition" OR "Acceptance"))

IEEE (Advanced Search for all Metadata):

("Information Technology" OR "IT Framework" OR "Information Technology Framework" OR "Information Systems" OR "Educational Technology" OR "ICT")

AND

("Infrastructure" OR "Infrastructures" or "ICT Infrastructure" or "ICT Infrastructures")

AND

("Architecture" OR "Architectures" OR "Design" OR "Pattern" OR "Reference" OR "Enterprise Architecture" OR "Reference Architecture")

AND

("Education" OR "School" OR "Secondary Education" OR "High School" OR "Senior School" OR "Secondary School" OR "Senior High School")

AND

("Rural" OR "Remote" OR "Village" OR "Isolated" OR "Developing Countries" OR "Developing country" OR "Emergent nations")

AND

("Implementing" OR "Implement" OR "Implementation" OR "Apply" OR "Execute" OR "Application" OR "ICT Implementation" OR "Adoption" OR "Acquiring" OR "acquisition" OR "Acceptance")

3.1.4 Inclusion and Exclusion Criteria

Table 3:Inclusion & Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
English peer reviewed studies	Studies that are not related to the research question and the sub-research questions
Studies published in Conference proceedings and Journal papers.	Duplicated articles by title or content
Study areas focusing in the fields of Computer Science, Engineering, Social Science, Medicine, Business and Energy	Studies that are too short or not complete

It is important to have certain criteria that help to filter out unrelated documents and filter in the most relevant ones. Therefore, Table 3 presents the inclusion and exclusion criteria. This also helps to reduce the bias in the SLR process (Kitchenham & Charters, 2007). For this SLR, the articles that satisfy the inclusion criteria in the table will be included. Similarly for the ones that the exclusion criteria apply will be excluded according to the table.

This thesis includes articles that are written and published in english as this ensures that it has been part of international conferences. The criteria of including papers that were either conference proceedings and journal papers ensures that they are of good standard and are reviewed by experts. This thesis also includes articles from that focus in the fields of Computer Science, Engineering, Business and Energy as these are the relevant fields. It also includes Medicine because new ICT infrastructure is introduced in rural and remote regions as plans of rural development in health care. Social Science is included to understand social factors of implementation. Further, this thesis does not include studies that are non-relevant to the research questions as this would result in deviation from the selected area. Duplicated articles across different databases and short or incomplete articles are also not included for this SLR.

3.2 Selection

This section describes the selection process. In order to avoid spending time on reading irrelevant articles and to avoid deviating from answering research questions accurately the gathered data needs to be synthesized first. This is done using a few steps, first is to run the search query in the selected databases, next is to apply the inclusion and exclusion criteria which is mentioned. These articles are then exported to ENDNOTE to read the title and abstract to eliminate non-relevant articles. The next step is to eliminate duplicates that exist is the different databases. This is done based on their title and abstract. The next step is to eliminate articles that cannot be accessed openly and those that do not have full text or documents that are incomplete. The final step is to select complete articles that help answering the research questions. By the end of this process 30 articles are selected to be reviewed. The selected 30 articles are provided in Appendix A and have labels P1-P30 and the abstracts of each selected article. Figure 4 represents the flow of the selection process.

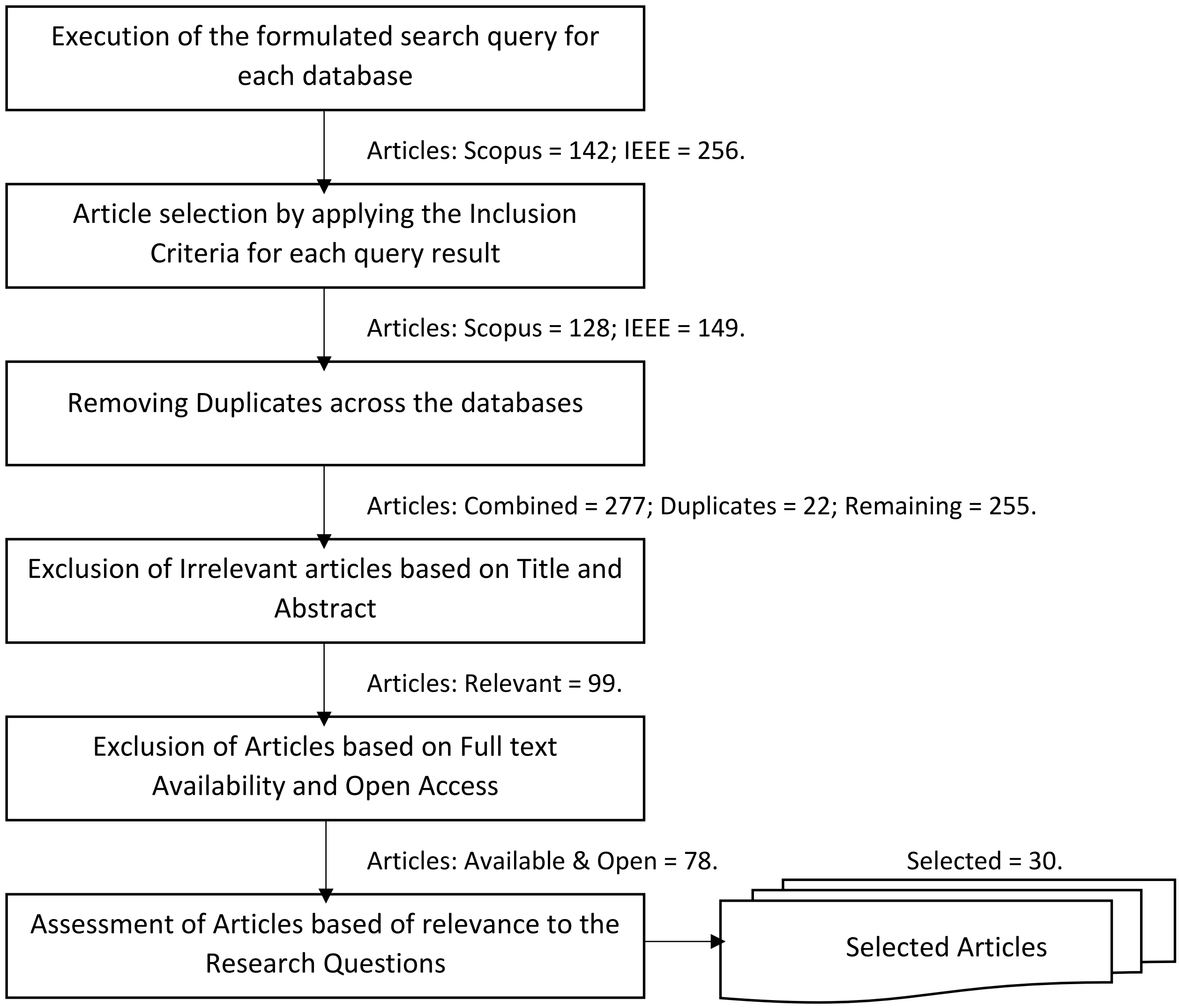

Figure 4: Selection Process

3.2.1 Data Extraction

After the selection of articles, the required information to answer the research questions should be gathered and synthesized. The important key aspects of each of the papers are listed and their relevant aspects to the sub-research questions are noted. It is important to categorize the selected articles according to the research questions and sub-research questions. This helps in identifying the relevant aspects that would lead to answering the questions previously formulated.

3.3 Result Analysis & Discussion

The results obtained from the previous data extraction are discussed here. The research question is answered here by answering the sub-research questions in respective order. First the challenges related to implementing IT in remote and rural regions, second the available solutions and then the requirements to implement IT in such regions are discussed.

Sub RQ1 for SLR: Challenges for implementing IT architecture

This section describes the challenges that are hindering the implementation of information technology in remote and rural regions. Many challenges that act as constraints for the same. These are presented in Table 4. Some studies mentioned the challenges in terms of technology, some as environmental and locational and some others as societal. To answer this sub-research question, this review refers to the similar challenges mentioned in multiple literatures.

Table 4: Challenges

#	Challenge Category	Challenges	Articles	
11	Geographical	Isolated; Dispersed; Difficult to access; Environmental Factors; Extreme weather conditions	P1, P5, P6, P7, P9, P10, P12, P13, P15, P16, P23, P24, P26, P28	14
2	Financial	Low Income; Lack of funding; Poverty; High Initial Costs; Expensive Materials	P1, P2, P3, P8, P9, P11, P12, P13, P16, P17, P18, P19, P20, P22, P23, P24, P25, P26, P27, P28, P29	21
3	Knowledge/skills	Low literacy rate; backwardness in terms of knowledge and education; lack of knowledge; Lack of knowledge, technical skills, ICT awareness, training, skilled staff, technical information; laggard concept; Educational environment	P1, P2, P3, P8, P9, P10, P11, P12, P14, P16, P17, P18, P19, P20, P21, P23, P27, P28, P29	19
4	Scarce Resources	Limited access to facilities; limited facilities; Limited infrastructure; lack of infrastructure, fixed telephone, reliable back channel, network infrastructure, new technologies, research, human resources, hardware, software, materials, service providers, learning materials, devices, transportation infrastructure; lack of water	P2, P5, P6, P7, P8, P9, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P27, P28, P29, P30	25

5	Policies	Lack of policies	P2, P3, P11, P12, P18, P20, P22, P27	8
6	Organization	Lack of Implementation, planning, strategies, space, communication	P3, P12, P22, P23, P27, P29	6
7	Support	Lack of development, local leaders support, teachers support, government; Political instability;	P3, P11, P13, P18, P23, P27, P30	7
8	Technical Support	Technical support after implementation; Telecommunication support; Monitoring; Mechanical Failure support; Maintenance; support services	P3, P6, P8, P13, P22, P23, P28, P29	8
9	Electricity	Lack of electricity; Power outages; unstable; Energy challenges; not connected to the grid; unreliable	P4, P5, P6, P10, P12, P13, P18, P20, P22, P23, P26, P27, P28	13
10	Internet	Unreliable; Unavailable; Expensive; Lack of Public internet; Connectivity issue; Large Bandwidth required; network Bandwidth failure	P5, P6, P9, P10, P13, P18, P19, P20, P23, P24, P26, P27, P29, P30	14
11	Number of learners	Large number of learners; overburdened teachers	P16, P18, P22, P27	4
12	Misc.	Animals Durability of materials No benefit to teachers English ICT adaptability	P13 P13 P18, P21 P23 P29	6

The gathered data shows that the challenges can be categorized. It is observable that, most challenges are faced in the category of scarce resources, financial and knowledge/skills. It can also be observed that constraints due to geographical conditions, electricity and internet also have a large impact.

Geographical challenges are mainly related to the location of the place where the ICT is to be implemented. Rural and remote regions lack access to modern technology due to their locations. These regions are also prone to floods, hurricanes etc. Extreme weather conditions make it difficult to even predict the type of materials to be used in designing the solutions. The population in these regions is also dispersed making it difficult to have reliable human resources for implementation. This also leads to lack of access to facilities and resources which is the biggest challenge as seen in Table 4. The lack of proper ICT infrastructure and limited access to the available ones make implementing solutions difficult as there are some requirements that are interdependent to implement solutions. Large number of students is an unprecedented challenge which is mentioned several times in the data collected. This is mainly due to dispersed population where educated people move towards urban areas to find better jobs (Sultana & Sultana, 2010).

Another major challenge faced is lack of funding or unavailability of funds to implement such projects. It is seen in most cases that ICT implementations in remote regions are largely dependent of foreign donations or NGOs (Heinrich, Darling-Aduana, & Martin, 2020). These challenges are linked to each other. As mentioned in (Diniz et al., 2006), lack of technology hinders the lower-income people to access lighting, communication, as well as many educational opportunities. Water resources are largely available in most of the regions and so is solar energy. Which makes it ideal for solution designers to think of solutions in renewable energy sectors (Hossain & Fatemi, 2009).

Sub RQ 2 for SLR: Available solutions for implementing IT architecture

Table 5: Available Solutions

#	Type of Solution	Articles	Number
1	Photo-voltaic cells	P1, P4, P12, P18	4
2	Satellite Communication & Radio Broadcasting	P1, P5, P6, P8, P15	5
3	Frameworks/Architecture/Models	P2, P3, P6, P7, P9, P10, P17, P20, P21, P22, P27, P28, P29, P30	14
4	Mobile devices	P5, P6, P7, P18, P23, P27, P29	7
5	Local Web Hosting	P5, P8, P10, P16, P17, P19, P29	7
6	Wi-Fi Mesh Network	P6, P13, P24	3
7	Community services	P6, P8, P18	3
8	Wired DSL	P6	1
9	E-Learning tools	P8, P14, P15, P22, P23	5
10	Raspberry Pi (IoT)	P12, P24, P29	3
11	Cloud Based Solution	P17, P25, P29	3

Table 5 gives a synthesized version of the gathered data that helps to answer the second sub-research question. This question speaks about the available solutions or solution types that would help in implementing ICT solutions in remote regions. From the table it is evident that a number of frameworks are available for the same such as Regulatory Framework, Cell Share Architecture, Village Phone Implementation Architecture, Model for Educational Development in Mountainous Area, Web Service Architecture, Industry 4.0 Framework etc. (Rahim, SunTie, Begum, & Sahar, 2011; Rahman, 2007; S. A. Sayed & Al-Rouh, 2008; Sharma, Belding, & Perkins, 2009; Suhardi & Wulandari, 2009; Svetsky, Moravcik, Mikulowski, & Shyshkina, 2021).

It is also to be noted that mobile devices are commonly used for bringing ICT to isolated areas, as these devices are ubiquitous, largely available, lower costs of acquiring and portable. There is also a growing trend in mobile phone coverage throughout the world (Sharma et al., 2009). This helps the development process as there is lower costs and lower maintenance involved. Another added factor that is mostly seen as a solution for internet is local web hosting. This makes sure that the connect is always available, responsive and reliable (Luk, Zaharia, Ho, Levine, & Aoki, 2009). To implement software as a solution there is a growing trend of e-learning seen especially with the help of multimedia class rooms (Lu, Tsai, & Wu, 2015). Other notable solutions were the use of PhotoVoltaic cells in combination with IoT tools like Raspberry Pi that are mainly used for energy purposes.

Sub RQ 4 for SLR: Requirements for the adoption of IT solutions

Table 6: Requirements

#	Requirement's category	Requirements	Articles	Number
1	Service Infrastructure	Trainings; Backend & Frontend support; Supply of Devices like Generator, mobile phones, cables, display units etc.; Access to devices; Knowledge & supply of software & hardware; Network provides; water; electricity; fuel; maintenance of devices	P1, P2, P3, P4, P5, P6, P7, P8, P11, P12, P13, P14, P15, P18, P20, P21, P24, P26, P28	18
2	Support	Local & Federal government; Stakeholder; Other students;	P1, P8, P9, P15, P16, P18, P20, P21, P22, P25, P26, P27, P28	13

3	Performance Measurement	Tools; Frameworks	P2, P11, P15, P26	4
4	Investment	Local; Donations; Savings	P4, P15, P25	3
5	Better Design	Replicability; Waterproofing; complexity; Accessibility; Scalability; Self-Contained; Ease of Use; Easy to deploy; Additional features, interfaces; Compatible; secure; monitoring; updating; Planning; Open-interoperability; elastic	P13, P16, P18, P23, P24, P25, P26, P28, P29	9
6	External Factors	Mindset & Culture	P2, P16, P28	3
7	Social Context	Trust	P16, P25, P28	3
8	Policies	Make & implement	P15, P26, P27, P28	4
9	Re-using/Sharing resources	Re-use existing infrastructure; sharing resources & vision	P8, P11, P28	3
10	Human Resources	Need for human work force	P13	1

The third sub-research question addresses the requirements needed to implement ICT in remote and rural regions. Table 6 addresses these requirements. The data gathered from the articles mentions different types of service infrastructure as the most required elements for any implementation. The services usually refer to the supply of devices, availability of network providers and network service providers, frontend and backend operations management, training of ICT use for the users etc. Mainly it is important to provide technical support to help operate the devices and systems in the ICT environment (Bishnoi & Suraj, 2020; Kaliisa & Picard, 2017). It is seen from the data gathered that involving local and federal governments along with other stakeholders plays a major role in satisfying the requirements of implementation process. The involvement of these people not only helps in grants and funds but also faster and better access to facilities and better online presence, internal processes and faster policy making (Rahman, 2007). These stakeholders have a bigger hand at improving the life of remote communities than any other person.

Another requirement while implementing ICT is to make sure that the ICT infrastructure is designed and produced in a better way, meaning to say the devices have better functionality and endurance than devices currently in use. The devices need to be replicable in remote environments, scalable and elastic and operable in these environments (Lo, Chan, & Ngai, 2016a). They should also be easy to deploy and use also withstand the extreme weather conditions of such environments (Ahmed, Hussain, & Farid, 2018; De La Concepcion et al., 2014; Talusan, Nakamura, Mizumoto, & Yasumoto, 2018).

The main research question of the SLR has been divided into three sub research questions to help answer it. The major challenges are the scarcity of resources and financial means to support the implementation. The available solutions point to the use of frameworks or architectures to aid implementation. This also adds to the fact that renewable energy resources, mobile devices and local hosting are solutions for implementing e-learning. The most import requirements needed to implement ICT is the presence of service providers and better design solutions.

4. Proposal for a Theoretical Model for Predicting the Adoption of Smart Education

Following the identification of the state-of-the-art for implementing ICT in remote and rural regions in the previous chapter, a theoretical model is to be derived. This includes identifying the determinants and implications for implementing ICT in remote and rural regions (Mukti, Henseler, Aldea, Govindaraju, & Iacob, 2022). This model will be further used to develop an artefact that will help achieve the final goal of this research.

4.1 Smart Education

It is important to define and identify certain terminologies before we start developing any model. Literature presents a number of different definitions for any given terminology. Therefore, it is important to arrive on one common definition and also present a clear background information of the same. Defining the terms also helps to describe the context for which the artifact is to be produced.

Gwak (2010) mentions smart learning as composed of two concepts; one focuses on learners and content, and the other on devices. Smart learning is an effective, intelligent and tailored learning based on IT infrastructure. Kim et al. (2014) mentions that smart education/learning is a learner centric and service-oriented paradigm rather than just the use of IT devices. Smart education focuses on educational services by ensuring learning and supporting academic achievement (Kuppusamy, 2020). These definitions give a learner's perspective of smartness.

Smart education also means the collaboration of advanced pedagogical practices, tools and techniques (Kiryakova, Angelova, & Yordanova, 2018) for the context of teaching and learning. Such collaborations can change the viewpoint of the entire teaching and learning process. It also helps improve the learning methods for students. Smart education is defined as an era by Santana-Mancilla, Echeverría, Santos, Castellanos, and Díaz (2013) who says that the concept of smart education is founded by the enhanced version of connectivity in the form of wireless interconnected networks between various types of devices. These definitions form the infrastructural viewpoint of smartness.

Keeping in mind the two angles defined earlier i.e., the learner's point of view and the infrastructural point of view, smart education can be defined as a modern form of education that aids the learners by providing new learning methods with coherent support of various IT infrastructure. In this definition there are three main aspects that are identified: The goal which is to provide new learning methods, the resources of IT infrastructure and the process of smart education along with the participation of the people involved. When the context of smart education is in picture the goal is clearly identified as providing better, faster, modern educational facilities that will help not only the learners but also the teachers and other stakeholders involved by providing them new tools and methods to carry out their necessary works. The identification of resources is done with the literature review carried out earlier. The challenges help to identify what resources are lacking and what needs to be provided to make implementing smart education easy. The process is also identified using the literature review where in the requirements and barriers are studied to note what processes would count for the implementation. Therefore, smart education is the key that facilitates the implementation of ICT infrastructure in rural and remote regions.

4.2 Stakeholders

Before the beginning of any model development, it is important to have a description of the context, contents, and workflow processes of the model. The context of smart education has already been described in the previous section. This section describes the contents that would be part of the model. The major impact of a model for implementing smart education in remote and rural regions would be on its stakeholders. This is mainly because the stakeholders form a major part of the model along with the processes and reap most of its benefits. This fits in with the definition of stakeholders who can be defined as people or groups who are in a relationship with an organization and also reap the benefits of the organization (Benn, Abratt, & O'Leary, 2016).

To have a better understanding of how the stakeholders of an educational system influence, participate and reap benefits of the model that is being developed, this research project categorises the stakeholders into three main categories. The categorization is done based on their interaction with the education system and the associated IT infrastructure with it.

The first category consists of stakeholders that are directly influenced by the educational system. They are also the first-hand users of the system. The educational system is mainly designed for the use and benefit of these stakeholders. Students, Teachers, Management and Educational Administrators form the first category of stakeholders. Students use the system for learning, submitting assignments or tests or exams, and also to keep up with the day-to-day activities. It is the learner who is at the centre of the educational process (Dolmans et al., 2002). Teachers are also the primary users of the system who use it for preparation, learning, teaching and other uses. Management uses the system for keeping track of the student and teacher database, student and teacher details, test scores etc. Educational Administrators use it for the overall administration of the system like admissions, registrations, curriculum development, strategy making etc.

The second category includes the indirect users of the educational system, such as the parents, policy makers, investors, and regional government. They do not use the system but highly influence the development of the system. Their main focus is the provision of services to the first category stakeholders with legal and financial support which makes the implementation of the educational system easy. Parents need to provide the basic amenities for the students to study with such a system. Policy makers play a major role in development of policies that help in the implementation of smart education by making relevant and effective policies. Investors are in the second category mainly because they do not use the system but are majorly responsible for the development of the system. Regional government or even the main government is responsible for building more schools, providing basic facilities like internet, electricity, water etc., by sharing the costs of development etc.

The third category of stakeholders are the people who are responsible for practically developing and maintaining the educational system. This includes the training providers, IT and service providers and third parties such as other universities, industries and Non-Governmental Organizations (NGO). The training providers are the people responsible for providing training to the first category stakeholders. As it is seen from the literature review that there is lack of trainings which act as a barrier for implementing and using such systems. IT providers are usually network providers, mobile phone companies, hardware and software providers who are responsible for the delivery of devices that form the educational system. Finally, the service providers are the ones that help in repairing and maintaining the system. The third category of stakeholders act as a bridge between the developing, implementing, using and maintaining phases of an educational system.

4.3 Educational Processes

Once the contents of the model have been defined, the next step is to define the associated processes. The stakeholders involve in an interactive process with each other and the educational system that make up the process flows of the model. The major processes that interact with the educational system are identified and described in this section. These processes form the core of the model, and the applications and devices that form the infrastructure to support these processes will be the technological requirements to realize the implementation of the same. The processes can be identified as core processes and supporting processes as shown in Figure 5. The core processes are the ones where the primary stakeholders (first group) are the participants, and the supporting processes are the ones where all the types of stakeholders participate. The major activities associated with the core processes interact majorly with the educational system and need IT infrastructure for information flow. The other processes indirectly account for interaction with the educational system. Following are the core and supporting processes based on the stakeholder interactions and have been represented in Figure 5:

Core processes:

1. *Student-Teacher interaction:* This process can be further divided into three types: communicative process which is associated with information sharing such as notes, important announcements etc.; interactive processes such as taking/giving lessons, tutorials, performing laboratory procedures etc.; perceptual processes such as evaluation of tests (Kovach, Deinega, Iatsyshyn, Kovalenko, & Buriachok, 2019).
2. *Student-Student interaction:* This process involves the communication of the students with each other for activities such as projects, laboratory experiments etc.
3. *Teacher-Management interaction:* This process involves the updates on the student’s database such as attendance marking, publishing test scores, and also on teacher’s database such as time-sheet filling, lesson plans, curriculum details, salary payments.

4. *Student-Management interaction:* Any updates to the student data, admissions, re-enrolments, fee payment form part of this process.
5. *Management-Management interaction:* Asset management, logistic management are part of this process.

Supporting processes:

1. *Teachers-Educational Administrators*: Curriculum development regarding implementing/usage of ICT in schools.
2. *Teachers-student-training providers interaction*: Providing trainings, knowledge transfer on how to use the system.
3. *Management-service providers interaction:* Maintenance of the system.
4. *Management-IT providers:* This process involves the supply of IT infrastructure.
5. *Educational administrators-Investors:* This process deals mainly with finances, audits, and its related aspects.
6. *Educational Administrators-Policy makers:* Policy making with guidelines, implementation of policies is part of this process.
7. *Educational Administrators-Government:* Implementing new schemes that support development of schools, getting feedbacks on current school systems.

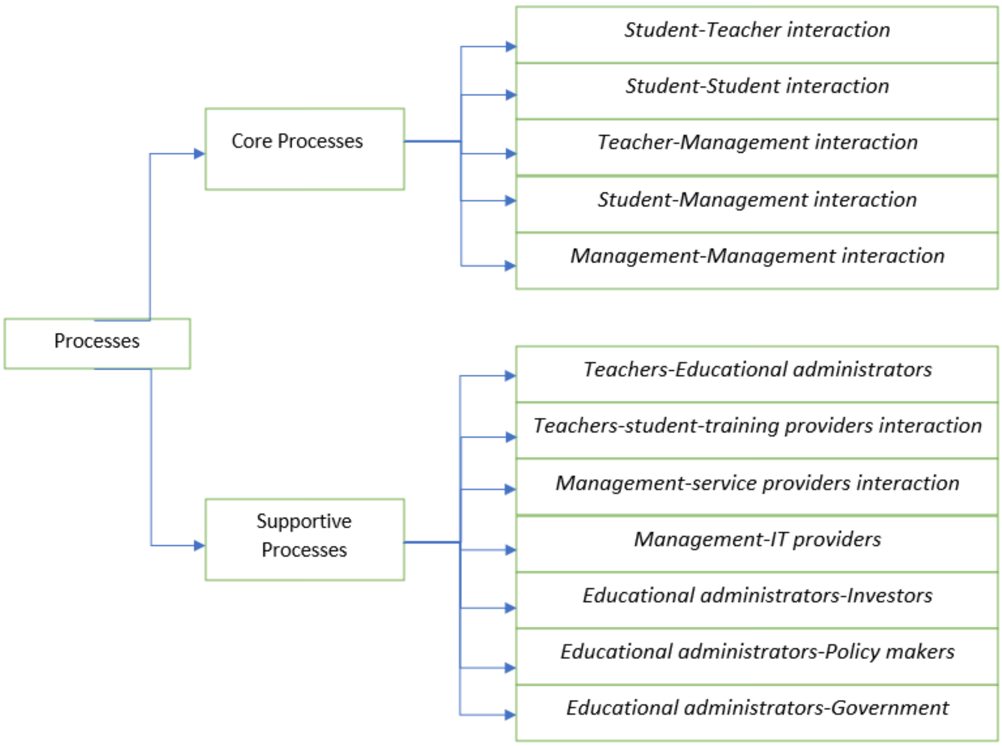

Figure 5: Educational Processes

Apart from these there are many other processes that form a major part of the school as an organization but, given the time frame and scope of this thesis only these have been considered.

4.4 Process oriented framework

Before we begin to model the artifact, it is good to know about the already existing frameworks, that would help to understand and develop the model. One of such frameworks is the process oriented framework (Mooney, Gurbaxani, & Kraemer, 1996). This is a conceptual framework that helps to link IT infrastructure and the performance of the organization. The framework focuses on the organization and its IT related processes. This is of relevance to the model being developed as it is important to link the IT infrastructure and the organizational processes of the schools. It incorporates three main aspects: (i) a typology of processes; (ii) a typology of potential impact of IT on those processes & (iii) analysis of the business value created by the impact on those processes. The framework suggests the classification of processes as operational processes and management processes which can be mapped onto core processes and supportive processes (in previous section) respectively. The operational processes are the ones where the tasks are done and management processes are associated with management related tasks such as administration, collaboration etc. as seen in Figure 5. The second aspect of potential impact on IT processes can be studied with the help of the literature review. The core processes have factors such as availability, reliability, adaptability that can have a major impact. The impact on supportive processes can be seen when there is better linkage from end-to-end of the devices, better communication, better access and availability of devices and so on. The analysis of the values created by the impact of IT on those processes can be linked to the strategies and goals for which the model is being created, such as provision of better and modern facilities in a teaching and learning environment of remote and rural schools.

Using these concepts of process oriented framework, the basic structure of the theoretical model can be depicted as shown in Figure 6. Although the framework applies to the context of an enterprise, it can be applied to institutions of education which are considered enterprises themselves which would also help them to move to the 21st century model of education (Caldwell, 2005). Going through digital transformations benefits the processes of an enterprise, its stakeholders and helps in value creation as a whole (Gebayew, Hardini, Panjaitan, & Kurniawan, 2018). "Digital transformations are transformations in organizations that are driven and enabled by new IT/IS solutions and trends" (Vial, 2019). Therefore, smart education can be considered as a digital transformation of rural and remote schools. In the initial model, *determinants* are the variables that contribute to the realization of smart education. These can also be defined as the factors required to perform the digital transformation. *Implications* are the benefits or impact analysis of having smart education.

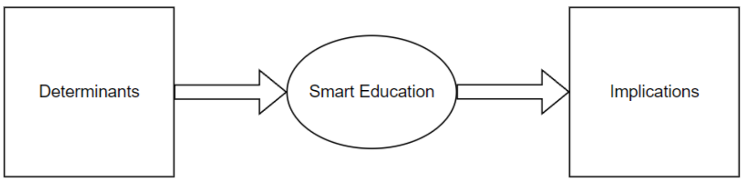

Figure 6: Base Model

4.5 Technology-Organization-Environment framework

This is a framework shows how elements in an enterprise influence the adoption of technology (Tornatzky, Fleischer, & Chakrabarti, 1990). As the name suggests, this framework classifies the elements as: Technological, Organizational and Environmental elements. Technological elements are the technologies that are currently available and being used by the enterprise, along with those technologies that are available in the market that could be useful for the enterprise. Organizational elements are the characteristics and resources of the enterprise such as the communication process, top-management support etc. The factors that facilitate and inhibit the adoption in the area where the enterprise operate form the environmental elements. These include the mind-set, cultural-issues, regulations, 3rd party resources, security and legal issues (Morgan & Conboy, 2013). This framework is widely used for adoption of new technologies in many scenarios such as cloud implementation, ERP systems, e-government adoption, digital technology enabled learning etc. (Gui, Fernando, Shaharudin, Mokhtar, & Karmawan, 2020; Oliveira & Martins, 2011; Pudjianto, Zo, Ciganek, & Rho, 2011; Singh & Alshammari, 2021). Given its wide applicability this framework can be used in the context of smart education to determine the factors that are needed to realize the implementation of ICT infrastructure which can be compared to the adoption of new technology.

This framework can be applied to this research project by referring to the literature review conducted earlier. The data gathered during the literature review is mapped onto the elements of the T-O-E framework. For example, the technological elements would include the electric supply with the help of grids, multi-media classrooms which are the current technologies in use and the available solutions such as photo-voltaic cells, radio and satellite communication, solar solutions could be the potential technologies that could be used. The organizational elements include investments, need for human resources, policy making, government support. The environmental elements refer to the social factors, mindset, support from other parties etc.

4.6 Rural Smartness Principles

This research adapts to the research conducted by Mukti et al. (2022)on rural smartness. Rural smartness is derived from the concept of urban smartness. A rural smartness model is formulated based on certain frameworks and empirically validated. This is a generalised smartness in the context of rural and remote areas. Mukti et al. (2022) also mention that this study can be used as a foundation for digital information platforms. Since the reference architectural model for smart education is a digital platform utilizing information systems and to provide education, the application and adaptability of the rural smartness model is justified.

According to Lusch and Nambisan (2015), IT can be seen as an entity that holds together the different stakeholders and enables collaboration within an enterprise. This concept is referred to as a service ecosystem. It is suggested that a creation of a service ecosystem enables better absorption and utilization of the resources withing the ecosystem (Mukti et al., 2022). This also enables better sharing of information among the stakeholders. Therefore, a rural educational organization as a service ecosystem is seen having better infrastructure and better digital technologies that enables sharing of resources and information among the teachers, students and other stakeholders.

Based on the fact that a rural school is a service ecosystem, and that the rural smartness model can be applied to it, four components of the model have been identified that apply to the context: connectedness, participatory governance, digitally empowered citizens and coherence of IT service provision (Mukti et al., 2022). The following definitions have been derived from the principle of rural smartness: Stakeholders who are the interacting entities of a rural ecosystem are interconnected by IT infrastructure and services; this is connectedness. The service exchange activities that involve the active participation of the stakeholders in the welfare initiatives is participatory governance. Digitally empowered citizens are the stakeholders of the service ecosystem. Lastly the coherence of IT service provision is the availability of a strategy that aims at providing coherent IT service (Mukti et al., 2022). Each of the components can be seen in the context of a smart education as well. Stakeholders use IT infrastructure and services for the execution of core and supportive processes which is connectedness. This is mainly concerned with information flow in all the processes. Participatory governance also referred to as Collaborative Governance is when the users of the system are able to participate effectively in the initiatives due to the availability of IT and this benefits them. It is referred to as collaborative instead of participatory because the initiatives will be more of a collaboration with all the stakeholders rather than mere individual participations due to the fact that the context here is an educational institute and the welfare is not referred as economic by qualitative welfare. Digital empowerment in the case of a rural school are the digitally skilled users of the system. The objective of provision of uninterrupted IT services by 3rd party vendors is the coherent IT service provision. These are the characteristics of smart education based on the rural smartness principle.

It is evidently seen in literature that there is need for new methods, ideas and theories in the era of digital transformation (Hinings, Gegenhuber, & Greenwood, 2018). On the other hand, digital innovation is seen as the orchestration of new products, processes, services platforms and new models and methods (Nambisan, Lyytinen, Majchrzak, & Song, 2017). This implies that innovations drive digital transformations. Which is to say that innovation can be seen as a key driver for implementing ICT in schools of remote and rural areas.

4.7 Formulation of the model

To formulate the model, we refer to the initial structure that was constructed in the previous section (Figure 6). The Technological-Organizational-Environmental framework is used to find the determinants of the model as mentioned earlier. The concept of service eco system and rural smartness principle is used to define the indicators of variables of Smart Education. The literature survey and the concept of innovation help to define the implications of the model. Based on these details, the model can be further developed as seen in Figure 7.

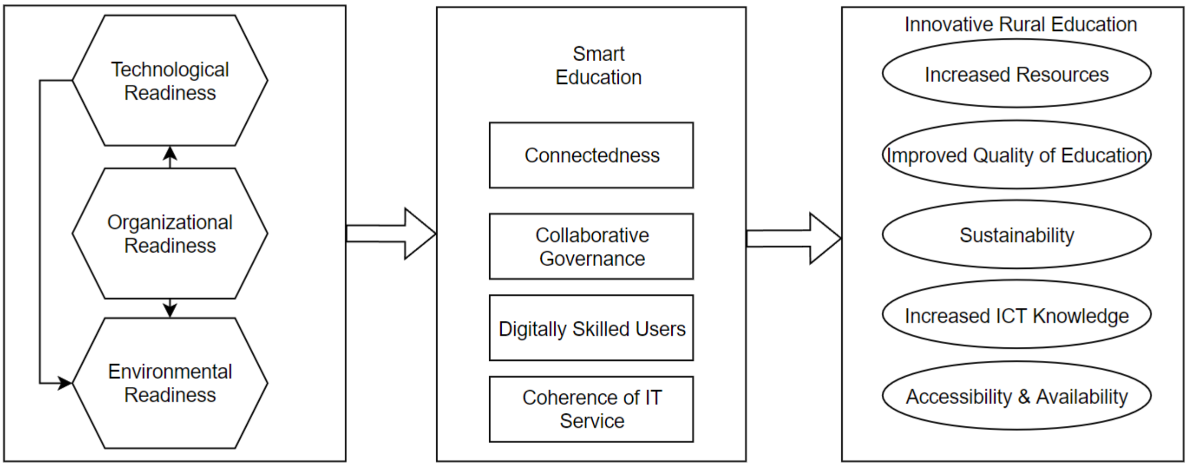

Figure 7:Theoretical Model for predicting the adoption of Smart Education

For the theoretical model two assumptions are hypothesized into the two general statements. (i) There are three variables that are inter-related and act as determinants for smart education. (ii) Innovativeness (not present in the Figure) as a variable acts as a driver for digital transformation. Therefore, the following variables can be derived from it: Technological readiness, Organizational Readiness, Environmental Readiness and Innovativeness. Among them the first three can be measured directly and represent concepts of design theory. They are also assumed to be inter-related to each other. These puts them under the classification of emergent variables represented using hexagons (Henseler, 2020). The variable innovativeness is a concept of theory, i.e., behaviour, abstract or cannot be measured directly and hence not seen in the model as a separate entity. This is a latent variable (Henseler, 2020).

4.7.1 Determinants of smart education

As mentioned earlier the Technological-Organizational-Environmental framework helps define what the determinants are for smart education. This is used along with the literature research conducted earlier. Firstly, it is important to define what determinants means for the context of smart education. Determinants are the factors that are required to realize smart education. As these are variables there needs to be a factor to measure them. The variables can therefore be measured with a degree of readiness (William E. Wagner, 2019). Therefore, it can already be seen in the literature survey what the challenges and requirements are to implement ICT for education in remote and rural regions. The challenges can be used as determinant variables to decide what barriers need to be overcome to implement smart education. Requirements are the things needed for the implementation as the name suggests.

4.7.2 Technological readiness

Technological readiness can be defined as the technological factor that is needed to realise smart education. Technological readiness variable is defined as the degree to which the technological elements are considered ready to realise smart education (Mukti et al., 2022). The indicators of technological readiness are derived from the challenges and requirements of the literature review conducted earlier. The major seven indicators are selected to gather the data. Internet Access, Stable Electricity, IT infrastructure accessibility and availability, IT Service Provision, Support services after implementation, Monitoring and Maintenance services, Training support. Therefore, technological readiness is concerned with the readiness or the degree to which the above-mentioned indicators are required to realise smart education in remote and rural regions. The Technological readiness variable, its definition and indicators are described in Table 7. These indicators can be either provided by the government, planned and strategized by the enterprise (here the schools), or even provided by 3rd party vendors (outsourced).

Rural and remote areas as the name suggests are characterised by remoteness, isolation and dispersed population. This is one of the main causes for lack of accessibility to resources and stable infrastructure provision (Luk et al., 2009; Sharma et al., 2009). This is also the reason for low communication among the stakeholders of the school as there is no stable electricity and stable internet. On the other hand literature suggests that having connection to stable internet and electricity reduces the communication gap in geographically isolated areas (Munkhtsetseg, Garmaa, & Uyanga, 2014). This not only helps better communication but also helps to boost online learning among the students and teachers from the broad world wide web and also boosts informal education among the peers. It helps to make availability and accessibility of study materials at all times. This increases the motivation of the children to participate and study more (X. Chen & Hu, 2020; Kolikant, 2010). The availability of materials also makes the students and teachers digitally skilled users as they use the internet to find useful information and also discuss important materials along with personal development (Vrasidas & Glass, 2007). The availability and use of ICT infrastructure positively correlates with urbanization (Caragliu, Del Bo, & Nijkamp, 2011), which is as good as a digital transformation. Formation of regulations at the department level support the easy implementation of e-learning (McGrath, 2006). Basically, technological readiness can be connected with the factors of e-learning. The following hypotheses can be formulated based on the technological readiness factors.

H1: Technological readiness influences environmental readiness for smart education

H2: Technological readiness influences the realization of smart education

4.7.3 Organizational Readiness

Based on the definition of determinants, organizational readiness variable can be defined as the degree to which the government and school as an organization are considered ready to realize smart education. Organizational readiness consists of the factors that form a major part of the top management and other organizational aspects. Organizational readiness is considered as a critical precursor for any type of complex change implementation to occur (Weiner, 2009). The most important actors for the context of a school like organization are the second category stakeholders identified earlier such as the investors. According to Mukti et al. (2022), the characteristics of a rural area can be seen with three perspectives; geographic, economic and human resources. It can be argued that the three are dependent on one another. Geographically rural areas are dispersed, and hence have low population (Diniz et al., 2006). The population is also poor, hence migration to bigger cities for jobs is seen as a typical rural characteristic (Cunha, Gomes, Fernandes, & Morais, 2020; De La Concepcion et al., 2014). This creates a low population is the rural areas, typically a low youth population. This geographical issue leads to a human resource issue by causing insufficient number of teachers to teach the large number of students (Lo et al., 2016a; Segooa & Kalema, 2015). The cause for migration is the economic condition of the citizens in those areas (Tacoli, McGranahan, & Satterthwaite, 2015). People living in the rural areas mainly depend on agriculture, poultry, or other jobs which do not fetch them as much income as in the urban areas. Even after moving to urban areas their economic conditions do not change much as they are invested in minimum wage jobs, daily waged jobs etc. due to low levels of education (Mitra & Murayama, 2009). Hence, the loop of geographic, economic and human resource condition remains as is. Given these conditions, it is not possible to rely on the rural population to make the necessary digital transformation of the rural schools all by themselves. Private sectors would have to invest a lot on all the infrastructure including the logistics to the maintenance provision. Private sectors invest with a view of return-on-investment benefits. And given the fact that the enterprise is an educational institution and not a profitable organization, no private sector would be interested to implement the reforms. Hence it is the duty of the government as a publicly elected body to realise smart education in these schools. Therefore, the organizational readiness of the school can be measured in terms of the regional/central government's readiness.

The following indicators for the organizational variable can be identified that needs to be realised by the government are Provision of Funds, Human Resources support, Strategies for IT implementation, Collaborations with private sectors, Policy Making Strategies. These along with the definition of organizational readiness have been indicated in Table 7. Firstly, the government needs to allocate funds for making rural areas developed by providing the basic IT infrastructure such as internet, electricity, network cables etc. which increases the connectedness among the stakeholders. To do so, the government can also collaborate with 3rd party vendors or private sectors, mainly because private sectors have access to superior technologies (Swanson & Samy, 2002). The government can also collaborate with a few non-profit organizations too. The NGO's provide a better social capital and are known to the context of rural development (Musgrove, 1996). This increases the interest among the population and makes them participate along with the collaborative bodies for their own development. The government should also bring in new policies and programs that would help implementing ICT easier. These include the policies are that range from coherent IT service provision in these regions to programs that mandate the inclusion of ICT in the curriculum for schools. This would give every student the right to digital literacy and IT education making them digitally skilled. These policies along with the new programs would also result in creation of job opportunities in the rural area. This would then mitigate the risk of rural to urban migration, increasing the human resources. Assuming the measures to be taken by the government as organizational readiness the following hypotheses can be formulated.

H3: Organizational readiness influences technological readiness for smart education

H4: Organizational readiness influences environmental readiness for smart education

H5: Organizational readiness influences the realization of smart education

4.7.4 Environmental Readiness

Table 7 represents the definition and indicators of environmental readiness. As seen from Table 7 the environmental factors are the culture and mindset of the people to accept IT, knowledge of IT already existing among the users, 3rd party involvement and departmental policies. There could be all the available resources required to use IT, but if the users do not accept it or intend the use it the availability of such resources is a waste. The literature review indicates that the mindset and culture of users is an important aspect for successful implementation of IT in any context. People need to trust and also have the willingness to use the resources for their day-to-day work. Lack of knowledge on how to use the system, lack of technical skills, lack of ICT awareness, lack of training, lack of trust on the device are the major factors that are currently acting as barriers to the use of ICT in rural region school. Also some of the teachers think that IT devices act as a disturbance rather than benefit for education (Svetsky et al., 2021).Therefore to increase the use of ICT and have better acceptance the mindset of the users need to be changed, they should also trust themselves to use the device correctly. This can be done so by having the users trained to use the system. The teachers can be assured that only education related aspects would be present in the system by having education specific software. On the other hand Technological Acceptance Models show us that the perceived usefulness and perceived ease are major factors that make the users accept new technology (Venkatesh & Bala, 2008). Therefore, the design of the system can be adjusted to have these factors included such as simpler user interfaces, and the systems should include multiple functionalities to cover the useful aspects.

As it is widely known, the demand of a product increases the supply. Similarly, having a large population of users in the rural environment willing to use new technologies, the demand of the technologies also in the rural environment increases. This can be seen with the example of mobile phone usage. The number of mobile phone users increase has led to increase in number of network providers (Masuki et al., 2010; Mpogele, Usanga, & Tedre, 2008). Studies also showed, involvement of parents helps in increased participation and reduction in failures by the students (Gertler, Patrinos, & Rubio-Codina, 2012). Along with the mindset of the users the involvement of 3rd parties plays a major role in the environmental readiness too. Non – Governmental Organizations play a crucial role in rural education as they bring in new innovative programs and also increased participation from students for multiple learning based educational activities (Jagannathan, 2001; Saud & Ashfaq, 2021). This also makes the users digitally empowered and triggers innovation in the context of rural education. Flexible regulations also make it easier to design, develop and implement new changes to the system without creating chaos. Therefore, environmental readiness variable can be defined as the degree to which the rural educational environment is considered ready to realise smart education. The following statement can be hypothesised:

H6: Environmental readiness influences the realization of smart education.

Table 7: T-O-E Variables and Indicators

Variable	Definition	Indicators
Technological Readiness	Degree to which the technological elements are considered ready to realize smart education	1. Internet Access 2. Stable Electricity 3. IT infrastructure accessibility and availability 4. IT Service Provision 5. Monitoring and Maintenance service 6. Training support
Organizational Readiness	Degree to which the government and school as an organization are considered ready to realize smart education	1. Provision of Funds 2. Human Resources support 3. Strategies for IT implementation 4. Collaborations with private sectors 5. Policy Making Strategies
Environmental Readiness	Degree to which the rural educational environment is considered ready to realise smart education	1. Culture and mindset of the people to accept IT 2. Knowledge of IT already existing 3. 3rd party involvement 4. Regulations for IT usage

4.8 Implications of Smart Education

From the model it is clear that, determinants are hypothesised to have an impact on smart education. Similarly smart education is hypothesised to have an impact on the implications of having smart education. The implications need to be variables that can be measured. There are many variables that are associated with the implications of having smart education. However, it is extremely difficult to measure every variable to check the impact of smart education. This is mainly due to the vast scope and varied definition of smart education. Smart education is seen as a digital transformation to a school. Digital transformations are considered the use of new technologies (Reis, Amorim, Melão, & Matos, 2018). Therefore, acceptance of new technology by the users and the benefits of it is what needs to be measured here. To maximise the impact assessment and minimise the scope, technology acceptance model can be used as reference. Based on Technology Acceptance Model (TAM) concept, any new technology is accessed based on its perceived usefulness and perceived ease of use (Venkatesh & Bala, 2008). Perceived ease of use anchors general beliefs about the technology and its usage. It also holds the beliefs about the technology that are based on direct experience with the system (Venkatesh, 2000). From these sentences it is clear that the perceived ease of use is associated with the mindset of the users, which is already addressed in the environmental readiness aspect. The perceived usefulness of the new technologies is what needs to be evaluated. Usefulness can also be seen as benefits. Therefore, perceived usefulness is the degree to which the stakeholders believe the realization of smart education will increase their well-being in terms of education.

4.8.1 Immediate Impacts of Smart Education

The digital transformation process when implemented on a rural school will enable many benefits to the stakeholders of the school. This section focuses on describing the benefits of having smart education in the context of a rural environment. The indicators of smart education can be seen in Table 8. First and foremost, the digital transformation enables communication remotely. This increases the efficiency of the entire teaching and learning process by saving the time spent to have physical interactions. The operation of the process becomes efficient and makes time for more productive work. Remote communication also eliminates the challenge of isolation. This leads to a collaborative way of working which helps the users to develop their social skills (Blau, Weiser, & Eshet-Alkalai, 2017). Collaborations also lead to innovation. This is due to the fact that they are supposed to combine the available resources to come up with solutions (Talbot, 2016). As a result, this leads to development of new knowledge based on a variety of pedagogical approaches (Blau et al., 2017).

On the other hand, a new form of education is introduced. The teaching and learning processes become easily accessible at the convenience of home. The teaching and learning process becomes more personal (Froese-Germain, 2014). Students become independent learners which motivates them to participate more in online learning activities (Hodges, Moore, Lockee, Trust, & Bond, 2020). Students will have more options to choose from and better choices of study materials. This gives them access to a wide range of learning resources. This expands the educational access of a student.

Due to the characteristics of rural schools that are isolated and remote, the main contributing factor to smart education relies on innovation. For the student's perspective, students are supposed to come up with innovative ideas to make use of the ICT infrastructure and services and for the teachers it relies on the innovativeness of coming up with new educational methods. The more the innovation, bigger implications can be seen. Based on the theoretical background and rural smartness principal *innovativeness* is a variable act as a driver to realize the benefits of smart education. Table 9 represents the variables of innovativeness and innovative rural education along with their indicators. Based on the descriptions of innovativeness and implications, the following can be hypothesised.

H7: Smart Education induces innovative rural education

Table 8: Indicators of Smart Education

Variable	Definition	Indicator
Smart Education	The degree to which smart education is realised	1. Connectedness 2. Collaborative governance 3. Digitally skilled users 4. Coherence of IT service

Table 9: Desired Value variables and indicators of Smart Education

Variable	Definition	Indicator
Innovativeness	The degree to which educational processes are considered to be innovative	1. Increased use of remote communication 2. Improved collaborations 3. New methods of teaching-learning
Innovative Rural Education	The degree to which the stakeholders believe the realization of smart education will increase their well-being in terms of education	1. Increased resources 2. Improved quality of education 3. Sustainability 4. Increased ICT knowledge Improved Accessibility and Availability

5. Empirical Validation of the Proposed Theoretical Model

To validate the proposed theoretical model, a survey questionnaire is sent to the participants of a village of in Dakshina Kannada district, Karnataka India. The population there is 4,443 people. Among them about 70% of them are literates, which shows their interest in education. This region is located in a remote area and is currently facing some of the challenges mentioned earlier in this research such as rural to urban migration, low network coverage, a smaller number of service providers, frequent power cuts, extreme weather conditions and also unreliable internet. These challenges were existing since a long time but came to the forefront only during the Covid-19 pandemic when all the work shifted to online modes. Even schools had to function online. The lack of available infrastructure and also lack of planning for the sudden migration to online school was a major challenge. Among the existing challenges the one that weighed the most during the pandemic was the internet issue. This fits well with the context of this research.

Another reason to choose this location is due to the plans that are also being implemented by the government. The government is showing huge interest in the network issues, majorly focusing on the internet issues, and coming up with plans and solutions for the same. Firstly, PM-WANI is a program that envisages provision of broadband through public Wi-Fi hotspot providers. It consists of the following elements:

- Public Data Office (PDO), which will establish, maintain, and operate PM-WANI compliant Wi-Fi Access Points and provide last-mile connectivity to deliver Broadband services to subscribers by procuring internet bandwidth from telecom service providers and/ or internet service providers.
- Facilitating PDOs in providing services to the end consumer.
- App Provider, who will develop an application to register users and 'discover' and display PM-WANI compliant Wi-Fi hotspots in the proximity for accessing the internet service and also authenticate the potential Broadband users.
- A Central Registry, which will maintain the details of App Providers, PDOAs, and PDOs. (India, 2020).

To facilitate ease of doing business and encourage local shops and small establishments to become Wi-Fi providers, it has been approved that the last-mile Public Wi-Fi providers require no license, no registration and will not need to pay any fees to Department of Telecom. PM-WANI is also a framework in itself by the government.

Along with this the government has come up with AIR-Fibre plans that help to access internet even when there is no electricity. With many such schemes in plan along with the aid of service providers and high interest of the local residents this place is striving and making the best of available resources to support education of the students in this area.

5.1 Data Collection

5.1.1 Respondents

Data is collected by the means of a survey. The survey consists of a certain number of questions that is related to the factors and the theoretical model designed earlier. The survey is distributed to a number of respondents who are either directly or indirectly linked to the implementation and use of ICT for educational purposes in the village of Subramanya. To make it easier and keep the research teaching-learning centric the survey was distributed to the teachers of this region. The teachers mainly use ICT for the purpose of teaching and also to hand out tests and other study materials. Especially during times of Covid-19, teaching also includes delivery of online lectures. The main reason for including only teachers is that they assume multiple roles when it comes to small rural educational institutes. Some of them are teachers who are also involved in the administration activities of the institution. Some of them also take up the role of board members and part-take in planning, developing and other activities required for running the institution. All the respondents understand the use of ICT for one or more purpose. The effectiveness can be determined by how much of ICT and the skills they know is applied to their actual work life.

5.1.2 Data Collection Procedure

The survey consists of questions that are to be answered using the five-point Likert scale (1= “strongly disagree” 2= “disagree”; 3= “neutral”; 4= “agree”; 5= “strongly agree”). The survey questions were formulated such that respondents understand the meaning of the questions and are able to answer them well. The survey was distributed to the intended respondents by online means. The link to the survey was sent using social media and email. The questions sent for the survey can be found in Appendix B.

A total of 57 responses were received. Out of them 52 were considered to be valid. The invalid responses had missing values. Such responses result in low data quality and hence were discarded from the final calculations.

5.2 Data Analysis

To empirically analyse the data that has been gathered, PLS-PM method is used. This method suggested by Benitez, Henseler, Castillo, and Schuberth (2020) is used to perform the analysis of the data mainly for the following reasons. Firstly, it can model both emergent and latent variables. Secondly, for small sample sizes PLS-PM gives better accuracy with the results. Finally, PLS-PM evaluates the overall fit of the model.

5.2.1 Estimation

ADANCO 2.3.1 was used for statistical analysis of the gathered data based on PLS-PM (Dijkstra & Henseler, 2015). The following settings were constant for the entire run. *Mode A consistent* for reflective measurement model. This ensures consistent estimation for path coefficients and loadings (Dijkstra & Henseler, 2015). To have weights proportional to the co-relation between the scores and the indicators *Mode A* is set to specify the structural model (Rigdon, 2012). Bootstrapping was used with 4999 bootstrap samples and maximum of 200 iterations.

5.2.2 Evaluation of measurement model

The measurement model specifies the relationship between the constructs and their indicators (Henseler, 2017). There are two types of measurement model in this analysis: Reflective measurement model and composite measurement model. The reflective measurement model consists of the latent variables and is the standard model for behavioural research. The composite model consists of emergent variables. In the analysis of the theoretical model defined earlier the reflective measurement model is applied to innovative rural education. The composite measurement model is applied to technological readiness, environmental readiness, organizational readiness and smart education.

Evaluation of the overall fit of the saturated model

There are two types of models in the ADANCO environment that provide the goodness and overall fit of the theoretical model. They are the estimated model and the saturated model. The estimated model is the model as graphically specified. ADANCO automatically generates a saturated model. It has the same measurement as the estimated model but there is no restrictions on the relationships between the constructs also known as variables.

In this sub-section the overall fit of the saturated model will be discussed. The validity of the measurements and composite models can be assessed with this, which is useful in avoiding a model misfit caused by misspecification of the measurement model (Benitez et al., 2020).

ADANCO provides several metrics to measure the overall model fit. They are the standardised root mean squared residual (SRMR), the unweighted least square discrepancy (d_{ULS}) and the geodesic discrepancy (d_G). Based on the results obtained by running the simulation with earlier mentioned specifications, it can be concluded that the saturated model has an acceptable overall model fit. This is because the d_{ULS} and d_G meet the criteria for a good model fit. This is based on the criteria set by Henseler (2017) where $d_{ULS} < HI_{95}$ and $d_G < HI_{95}$. Which imply that atleast two out of the three metrices satisfy the condition to be a good model fit (Mukti et al., 2022). Although the SRMR was not below the threshold of 0.08, it is below the values for the 95th percentile (HI_{95}) and the 99th percentile (HI_{99}). Showing that it is still acceptable. The details of overall saturated model fit evaluation can be seen in Table 10.

Table 10: Overall Saturated Model Fit Evaluation

Discrepancy	Value	Threshold	Conclusion
SRMR	0.1060	0.0800	Not Supported: SRMR > 0.0800
d_{ULS}	3.1022	HI_{95}: 3.733; HI_{99}: 4.8561	Supported: $d_{ULS} < HI_{95}$
d_G	1.9089	HI_{95}: 3.7600; HI_{99}: 4.9222	Supported: $d_G < HI_{95}$

Assessment of the reflective measurement model

The reflective measurement model gives the relationship between the latent variables and their observed indicators. This assessment involves three measurements: Composite reliability, convergent validity and indicator reliability.

Composite reliability also known as Dijkstra-Henseler's rho (ρ_A) is an estimation of the reliability of construct scores pertaining to a reflective measurement model (Henseler, 2017). It gives the co-relation between latent variable and construct scores. A value of 0.707 for ρ_A can be regarded as reasonable as more than 50% of the variance in the construct scores can be explained by the latent variable (Nunnally, 1967). Therefore, for the results state that the latent variables in the model have composite reliability.

Convergent validity also known as Average Variance Extracted (AVE) is equal to the average indicator reliability. It is typically the measure of uni-dimensionality. AVE value greater than 0.5 is suggested to provide empirical evidence for the same. The corresponding latent variable explains more than half of the variance in belonging indicators and latent variables explain less than a half (Fornell & Larcker, 1981). The value for innovative rural education for AVE indicates convergent validity.

Indicator reliability measured by the factor loading evaluates whether indicators that measure a particular latent variable are reliable. The general advice for factor loadings is to be greater than 0.707, but somewhat lower values are not problematic as long as other criteria are met. The results obtained are all significant on a 1% level, suggesting they are reliable.

As there is only one latent variable present the HTMT criteria is not significant in this case. The following Table 11 shows all the reflective measurement model evaluation and their values.

Table 11: Reflective measurement model evaluation

Code	Indicator	ρ_A	AVE	Loading
Innovative Rural Education		0.8582	0.7929	
IN2	Improved Collaborations			0.9592
IN3	New methods of teaching -learning			0.7832
PU1	Increased Resources			0.4690
PU2	Improved Quality of Education			0.5308

Assessment of composite measurement model

The objective of doing composite measurement is to evaluate the relationship between emergent variables and their indicators. A loading shows the absolute contribution of an indicator to its construct (Benitez et al., 2020). Therefore, the weights and loadings of the indicators were assessed to evaluate its relative and absolute contribution to the variable. Table 12 represents the weights and loadings of the indicators and their variables.

Table 12: Composite measurement model evaluation

Code	Weight	Loadings
Technological Readiness		
TR1	0.2244***	0.7536***
TR2	0.1530**	0.6352***
TR3	0.2433***	0.7427***
TR4	0.1456*	0.5805***
TR5	0.2812***	0.7999***
TR6	0.3083***	0.7902***
Organizational Readiness		
OR1	0.1142	0.5431**
OR2	0.3430**	0.5957***
OR3	0.3111***	0.8112***
OR4	0.3439***	0.7476***
OR5	0.2952**	0.7596***
Environmental Readiness		
ER1	0.2660***	0.6078***
ER2	0.2738***	0.6414***
ER3	0.3900***	0.7809***
ER4	0.4301***	0.8326***
Smart Education		
SE1	0.3408***	0.8391***
SE2	0.3675***	0.8216***
SE3	0.3113***	0.7197***
SE4	0.2686***	0.7000***

p<0.10, *p<0.05, **p<0.01, ***p<0.001, one tailed test

5.2.3 Evaluation of the structural model

To assess the relationship between all the variables that were described in the theoretical model, a structural evaluation of the model is done (Henseler, Hubona, & Ray, 2016). This includes the overall fit of the estimated model, the path coefficients between the variables and their effect sizes, and the coefficient of determination of R^2 (Benitez et al., 2020).

Evaluation of the overall fit of the estimated model

To obtain empirical evidence for the theoretical model the overall fit of the estimated model should be obtained. Benitez et al. (2020) describes that there is a high chance that the proposed hypotheses accurately describe real phenomena if the overall model fits adequately.

As seen from Table 13 the values provide enough empirical evidence that the proposed model fits well which explains the determinants and the impacts of Smart Education. Even though the SRMR was a little above the threshold of 0.08, it was still below the 95th and 99th

percentile. Also the values for d_{ULS} and d_G are below HI95 indicating the estimated model was not rejected (Benitez et al., 2020).

Table 13: Overall estimated model fit evaluation

Discrepancy	Value	Threshold	Conclusion
SRMR	0.1090	0.0800	Not Supported: SRMR > 0.0800
d_{ULS}	3.2811	HI_{95}: 4.0451; HI_{99}: 5.0530	Supported: $d_{ULS} < HI_{95}$
d_G	1.9219	HI_{95}: 3.7802; HI_{99}: 5.0066	Supported: $d_G < HI_{95}$

Evaluation of path coefficients and their effect sizes

Path coefficients are interpreted as change in dependent variables measured by standard deviations if the independent variables are increased by one standard deviation while keeping all other independent variables constant (Benitez et al., 2020). A path coefficient is considered statistically significant when its p-value is below the pre-defined α level (Henseler et al., 2016).

Cohen's f^2 signifies the effect sizes. The practical effects are investigated by considering the effect sizes of the relationships between the variables. It is the measure of the magnitude of an effect that is independent of sample size (Benitez et al., 2020). The f^2 values ranging from 0.020 to 0.150 are considered weak, 0.150 to 0.250 are considered moderate and values equal to larger than 0.350 are considered to have large effect size (Cohen, 2013).

Table 14 shows the results for path coefficients and effect sizes. The table also shows the proposed hypotheses and if they are supported or not. The interpretations of these will be discussed later.

Table 14: Results of path coefficients and effect sizes

Hypothesis		Path Coefficients	Hypothesis Results	Effect Size (f^2)
Technological Readiness → Environmental Readiness	H1	0.5040***	Supported	0.4290 (*strong*)
Technological Readiness → Smart Education	H2	0.1900	Not Supported	0.0511 (*weak*)
Organizational Readiness → Technological Readiness	H3	0.4106***	Supported	0.2027 (*moderate*)
Organizational Readiness → Environmental Readiness	H4	0.3375**	Supported	0.1924 (*moderate*)
Organizational Readiness → Smart Education	H5	0.0240	Not Supported	0.0010 (*no effect*)
Environmental Readiness → Smart Education	H6	0.6178***	Supported	0.4573 (*strong*)
Smart Education → Innovative Rural Education	H7	0.5450***	Supported	0.4226 (*strong*)

***p<0.001; **p<0.01; *p<0.05

Evaluation of R^2

R^2 is usually used to check if the research is future-proof. The conclusions drawn are relative to the theoretical maturity of the phenomena under investigation. For phenomena that have research already progressed quite well the R^2 value is relatively high. However for new studies that are less understood lower R^2 values are seen and are also acceptable (Benitez et al., 2020). This shows that the study of Smart education in the context of innovative rural education is still in its initial stages as seen with the values of R^2 in Table 15.

Table 15: R^2 Values

Variable	R^2
Technological Readiness	0.1686
Environmental Readiness	0.5077
Smart Education	0.5891
Innovative Rural Education	0.2971

5.3 Discussions

5.3.1 Major Findings and interpretations

***Finding 1**: Technological readiness has a strong direct effect on environmental readiness but has no direct contribution on the realization of rural smartness.*

This finding discusses the hypotheses H1 and H2. The first half of the statement shows that technological elements contribute well to prepare the environment for a smart education system. The second half of the statement emphasizes on the fact that, mere presence of technical devices or services is not enough for the realization of smart education in a rural setting. But it can be seen from Table 14 that environmental readiness contributes well for smart education. This shows that there is need for environmental readiness to accept technological readiness for the realization of smart education. To elaborate on the same, IT devices such as computers, mobile phones, etc. in the hands of users who refuse or hesitate to use it is of no use. To realize the full potential of smart education type of a system, the user must have some knowledge on how to use it and should also accept that these technologies are for the benefit of themselves and society at large. It is also seen that the factors such as internet access, infrastructure accessibility, monitoring and maintenance and training support have a greater influence on technological readiness. Whereas IT service provision has not much of an effect. This may be due to the fact that there are already a large number of service providers currently available after the pandemic situation.

***Finding 2**: Organizational readiness has a moderate positive effect on technological readiness and environmental readiness but has no direct effect on the realization of smart education*

The hypotheses H3, H4 and H5 contribute to the discussion of this finding. Organizational readiness mainly consists of the readiness of the government, the above statement emphasizes on the fact that readiness of the government has a direct effect on other readiness factors. This provides a good validation that the government is the key role player for realizing smart education. Technological elements and organizational elements rely mainly on the government. In this research the major finding is that funding does not constitute as a major indicator to organizational readiness. One of the reasons for this could be because the government is not contributing directly in the form of funds but coming up with different initiatives that contribute IT infrastructure development in the regions. Although there have been plans and programs that have been initiated by the government in rural regions such as Air Fibre, PM WANI etc, these projects during the time of conducting the survey were just in the initial phases of deployment. Also, these services address the technological readiness to a certain extent. The government focuses on provision of services and internet and not on provision of IT devices. Another reason is that the users have not used these plans majorly for the purpose of education. The benefits of such programs were mainly concentrated for entertainment and general purposes and not mainly on education sector. The main reason for no effect on realization of smart education could be drawn to the fact that the main role of the government is to ensure the technological and environmental readiness through fundings but not smart education itself.

Finding 3: *Environmental readiness has a strong positive effect on the realization of smart education.*

Finding 3 discusses the hypothesis H6. The above statement proves that the most important thing for realization of smart education constitute culture and mindset of the people, some existing knowledge about IT usage, 3rd party collaborations and Regulations. For the context in this research, the participants in the are willing ready to adapt to new technologies that would help them in their educational processes. An added contribution to this willingness is the existing knowledge and familiarity on how to use the devices and services. The users are using IT devices mainly for communication purposes which helps them to adapt to using it for other reasons easily. Although there has been a neutral response on the involvement of 3rd parties in that particular region, it has been noted that many NGO's and industries have taken initiatives in the nearby regions and other parts of India to come up with such/similar educational systems. The most noted ones are eVidhyaloka and Barefoot college and Infosys. There are some existing policies that the institutes came up during the pandemic to inculcate IT in their daily education as well. These also justify the strong effect of environmental readiness on realization of smart education.

Finding 4: Smart Education has a strong positive effect on Innovative Rural Education.

The hypothesis H7 is discusses in this section. This statement shows that having systems like Smart Education play a major role in achieving innovative rural education. The key factors that smart education systems possess drive innovation in rural education. This can be explained by the availability of devices and internet that help in accessing new and wide range of information. This is also supported by the survey results that stated that students had better and new opportunities due to the presence of IT. Especially the entire view of teaching and learning changed when there was a necessity to use IT infrastructure for educational purposes, i.e., during the pandemic of Covid-19. Therefore, these claims prove that smart education like systems changes the way for rural education in developing countries.

5.3.2 Implications of the empirical validation process

There are some practical implications to the above analysis and findings. The most important one is related to the funding that needs to be taken care by the government. This indicator of funding ensures that the other readiness factors are in check. It has been noted during the analysis that the participants of the survey claim that the government is not doing enough to gather funds for initiating such projects. Without the funding there is going to be no devices, no services and ultimately no stakeholder involvement in the use of such systems. The results also suggest that by just having the devices and technology or having enough funds and government policies, it is not possible to ensure that there would be smart education. It is important that the users have the mindset to accept these technologies along with some pre-existing knowledge on the usage of the system for it to be integrated into their daily lives. Also, involvement of third parties to come up with initiatives and not being solely dependent on the government is to be noted. Finally, it can be implied that, the factors that constitute smart education play a direct and major role in innovating rural education.

From the theoretical perspective, the overall goodness of fit of the model gives a suggestion that the model is well validated and could be used for further research in the field of Smart Education or similar contexts. It is also noted by the R^2 value that there has been very low research in this field. This calls for a need for research to develop in this direction. Such research can help in a better understanding of the requirements of rural educational sector. As suggested in a broader perspective of rural smartness the emergent variables of Smart education can also be translated into a set of functional requirements in designing an IT artefact (Mukti et al., 2022). This is done in the subsequent chapter of this thesis.

5.4 Limitations of the empirical validation

There may be some possible limitations to this research. First, the data collected is only from a particular region. Although the results can hold true for other institutions in other areas as well with similar contexts, these results can be a threat when we try to generalize them. There could be a possibility the results may differ or falsify when applied to a similar context but a different country. As a suggestion for future research, it could be recommended to take samples from different regions for analysis. The data gathered has only the perspective of teachers, the student's perspective is missing which could change certain findings of this research. Second, the sample size is less when compared to high end research. A larger sample size usually helps identity significant relationships in the data in a better way. Finally, we have only evaluated unidirectional relationships in the theoretical model. This is because the data gathered does not support the study of bidirectional relationships. Therefore, future research could investigate such possibilities.

5.5 Conclusions of the empirical validation

This chapter conducted a survey in a rural region that faced some major crisis during the pandemic due to a lack of IT infrastructure. The survey aimed at gathering data to analyse and report the empirical model that explains the major factors (determinants and indicators) that influence the adoption of smart education in such regions. The following findings and recommendations have been drawn from the analysis.

1. The organizational factor is the major one that is responsible for most of the initiatives as it has a strong influence on other readiness factors (Technological and Environmental). The government is the driver of all organizational readiness factors. Hence it is the responsibility of the government to take up initiatives to implement such projects in rural and remote regions. The main requirement here is of human resource support, collaborations with private sectors and also to come up with policies for implementing the usage of IT in the region.

2. Even though internet access, accessible and available IT infrastructure, monitoring and maintenance of the same along with training support is needed, the presence of technology only is not enough to realize smart education. It is important to have environmental factors such as mindset and culture of the people to use those technologies, adequate trainings to know how to handle the devices at hand and policies and guidelines on how to use them for educational purposes also present along with technology. Also, involvement of industries and NGOs are playing a major role to have the environment set to implement smart education.

3. And finally for the smart education itself when implemented innovates rural education, which in-turn improves the education process benefitting not only the students but the entire society. Also, its characteristics can be translated and developed into a detailed architecture which can be useful for future research.

6. Proposing a Reference IT Architecture for Adoption of Smart Education

As mentioned in the earlier chapter the emergent variables of the theoretical model can be used to develop an IT artefact. The artefact here would be the architectural model for implementing smart education. This can be done by translating the variables into a set of functional requirements. These requirements then can be translated into services that serve smart education in rural environments.

Archi is a modelling toolkit that helps in realizing architectures of such theoretical models. It is a low-cost, open source, cross platform ArchiMate modelling tool which engages with the TOGAF language or any Enterprise Architecture Framework. It not only helps in supporting the description and analysis of the architecture but also in its visualization across all business units which can each be represented as individual viewpoints. The 1st Chapter of this thesis describes the different layers and other details of ArchiMate.

Each of these viewpoints are the enterprise architecture models for implementation of smart education like platform in rural and remote regions. The architecture for smart education consists of the following viewpoints:

1. Motivational Viewpoint
2. ICT infrastructure Viewpoint
3. Application Interface Viewpoint
4. Government Collaborations viewpoint
5. Training Viewpoint
6. Third Party Collaboration Viewpoint
7. Final Architecture Viewpoint

6.1 Motivational Viewpoint

The motivational viewpoint represents the intention behind the design of the architecture. figure 8 represents the motivational viewpoint. Understanding the fact that motivations have drivers in them that lead to certain goals, the top elements in Figure 8 are designed as follows. The innovation of rural education is composed of the five indicators of theoretical model: Increased resources, Improved quality of education, Sustainability, Increased ICT knowledge, Accessibility and Availability. The drivers of these would be the increased use of remote communication, improved collaborations and new methods of teaching and learning as described in the immediate impacts of smart education sub-chapter.

The indicators of smart education have been modelled as capabilities in the model. Smart education as an application component employs resources to realize the goal of innovative rural education (Azevedo et al., 2015). Smart education indicators are associated to the technological, organizational and environmental readiness contexts which have been modelled as assessments with a goal to realize them.

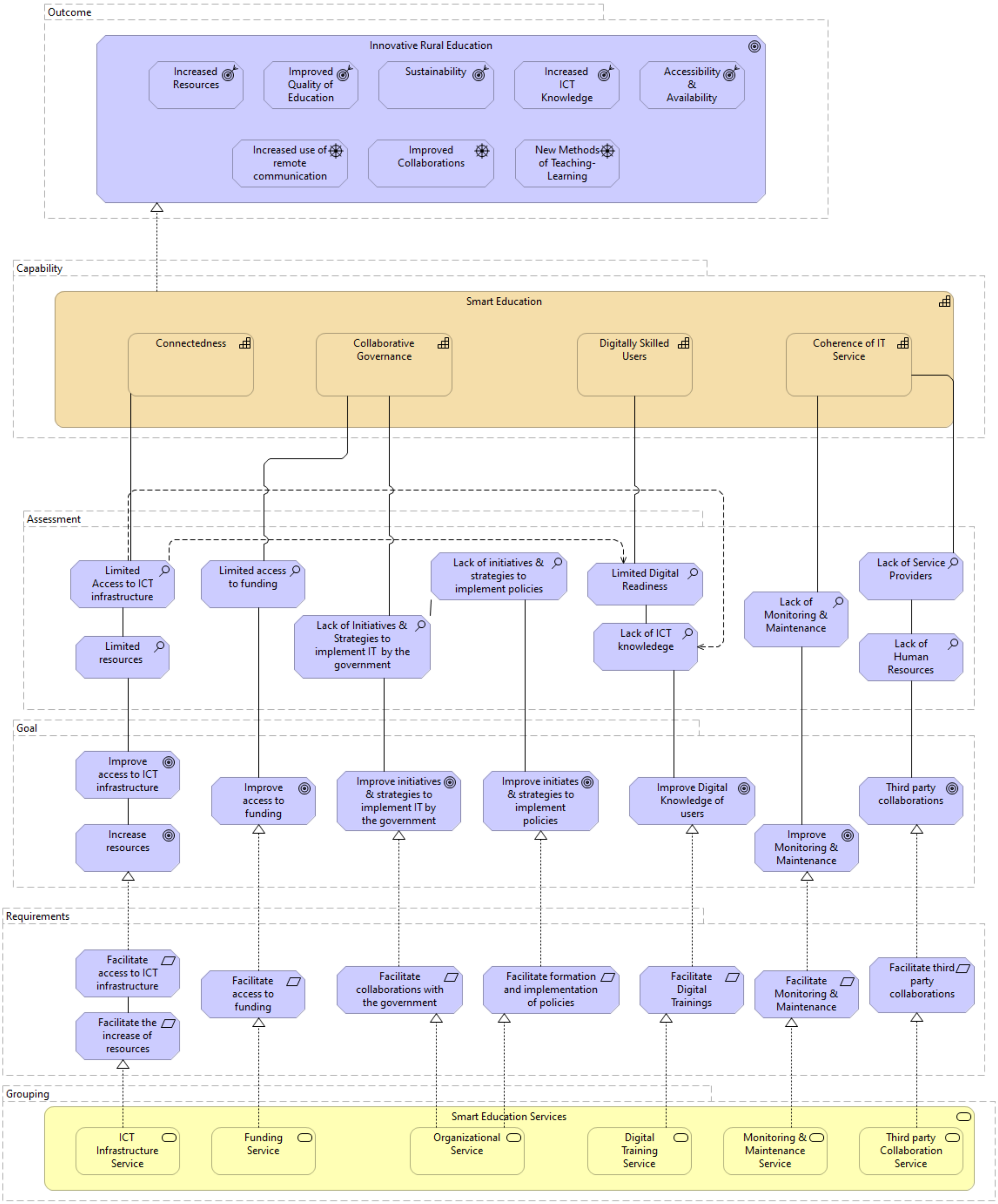

Figure 8: Motivational Viewpoint

Based on the literature review conducted in Chapter 3, requirements for implementing IT in such regions have been modelled as requirement components in the motivational viewpoint model which realize the goals assessed. The main reason for modelling them as requirements is that before the design of any system (Smart Education platform) it is important to define the functional and non-functional requirements of the system that define its architectural requirements (Nakagawa, Guessi, Maldonado, Feitosa, & Oquendo, 2014). Following this ideology, the following requirements have been identified: to facilitate access to ICT infrastructure (Diniz et al., 2006; Rahman, 2007), the increase of resources (De La Concepcion et al., 2014; Suhardi & Wulandari, 2009), access to funding (Hossain & Fatemi, 2009), collaborations with government (Diniz et al., 2006; Rahim et al., 2011), formation and implementation of policies (Heinrich et al., 2020; Owen, White, Palekahelu, Sumakul, & Sekiyono, 2020), digital trainings (Bishnoi & Suraj, 2020; De La Concepcion et al., 2014), monitoring and maintenance (Lo et al., 2016a) and third party collaborations (Tom, Virgiyanti, & Rozaini, 2019). Each of these requirements will then be architected into individual services that will be realized by the smart education platform.

6.2 ICT Infrastructure Viewpoint

In association with the services shown in the motivation viewpoint, the main aspect of this thesis is the ICT infrastructure Service which should be elaborated further into a separate viewpoint. This viewpoint shown in Figure 9 depicts the components of the information systems and their relationships, along with the supported processes or services of the smart education platform. This viewpoint adds more details towards the technological elements that form the Technological readiness of the system.

The rural educational institute constitutes of the users of the system who are the teachers, students, management and educational administrators as described earlier. They access the educational platform through the ICT facility available in the institution. The smart education platform as an application component realises a set of services at the business level (Pańkowska, 2016). These services will be translated into processes and described in the next section. One of the services of the platform is to provide support when a user needs help in using the system. This is mainly required because the users may not be familiar with the system (S. Al sayed, 2008). The smart education platform should provide the users with the functionality to help them navigate through the system and display the support contact details.

In order to realize these services, systems software is present consisting of IT management software, Library management software, Employee management software, student management software and Learning management software. The software interacts with the application component through application programming interface. The software needs a backend database to store all its data which in the architecture is represented with the technological component. It consists of various data objects that are used by the system software. Other hardware devices and the communication network (LAN) represent the networking aspects of the infrastructure architecture (Luk et al., 2009). This addresses the challenge of unreliable network by the presence of local communication networks (Selviandro, Suryani, & Hasibuan, 2015). The presence of a PM WANI service is the representation of the initiative started by the Government, where residents of a region can act as service providers by sharing internet hotspots. It can also be the local post office which provides a similar service for a low price.

The service provider as a business role consists of the internet, hardware and software vendors who realize the service provision of their respective products. The monitoring and maintenance are seen as a collaboration service provided by these vendors. This is based on the evidence that service providers provide technical assistance and technical feedback (Gómez Fernández & Crespo Márquez, 2009). Further this can be extended to the functionality of basic monitoring and maintenance. The representation of a remote user is also seen on the architecture, which provides evidence for increasing remote communication among the users to achieve innovative rural education. The entire ICT facility can be supported by the provision of electricity through power supply grids consisting of PV cells (Lo, Chan, & Ngai, 2016b).

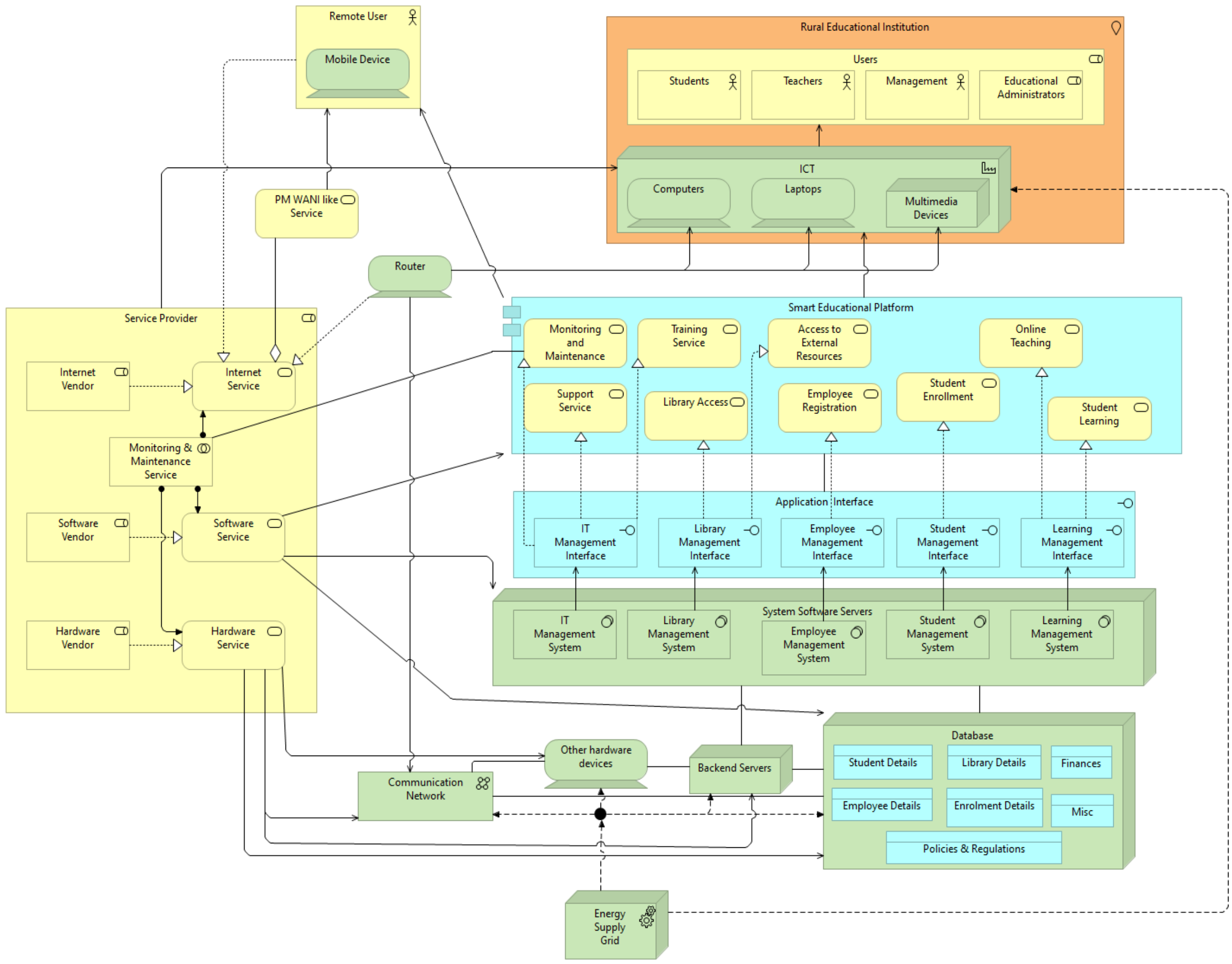

Figure 9: ICT Infrastructure Viewpoint

6.3 Application Interface Viewpoint

In order to further explain what happens within the smart education application component and the application interface the application interface viewpoint is presented as shown in Figure 10. This type of viewpoint shows the internal working of the application platform, that realize its business services through business processes. The main educational processes described earlier are architected to be fit into the system. They are the support, training, employee registration, student enrolment and the teaching-learning processes.

The business service when accessed triggers an application event in the application interface, which furthers triggers an application process or application function to realize the service. E.g.: the training service triggers the training request event, which in-turn triggers the process of searching the database for the requested training which displays the video for the requested training. The architecture viewpoints presented here are intended to be as general as possible following only the architecture requirements. It does not explain the details of the processes and/or other sequential activities. This is mainly because the business process differs from one educational institution to the other and also differ from one application to another.

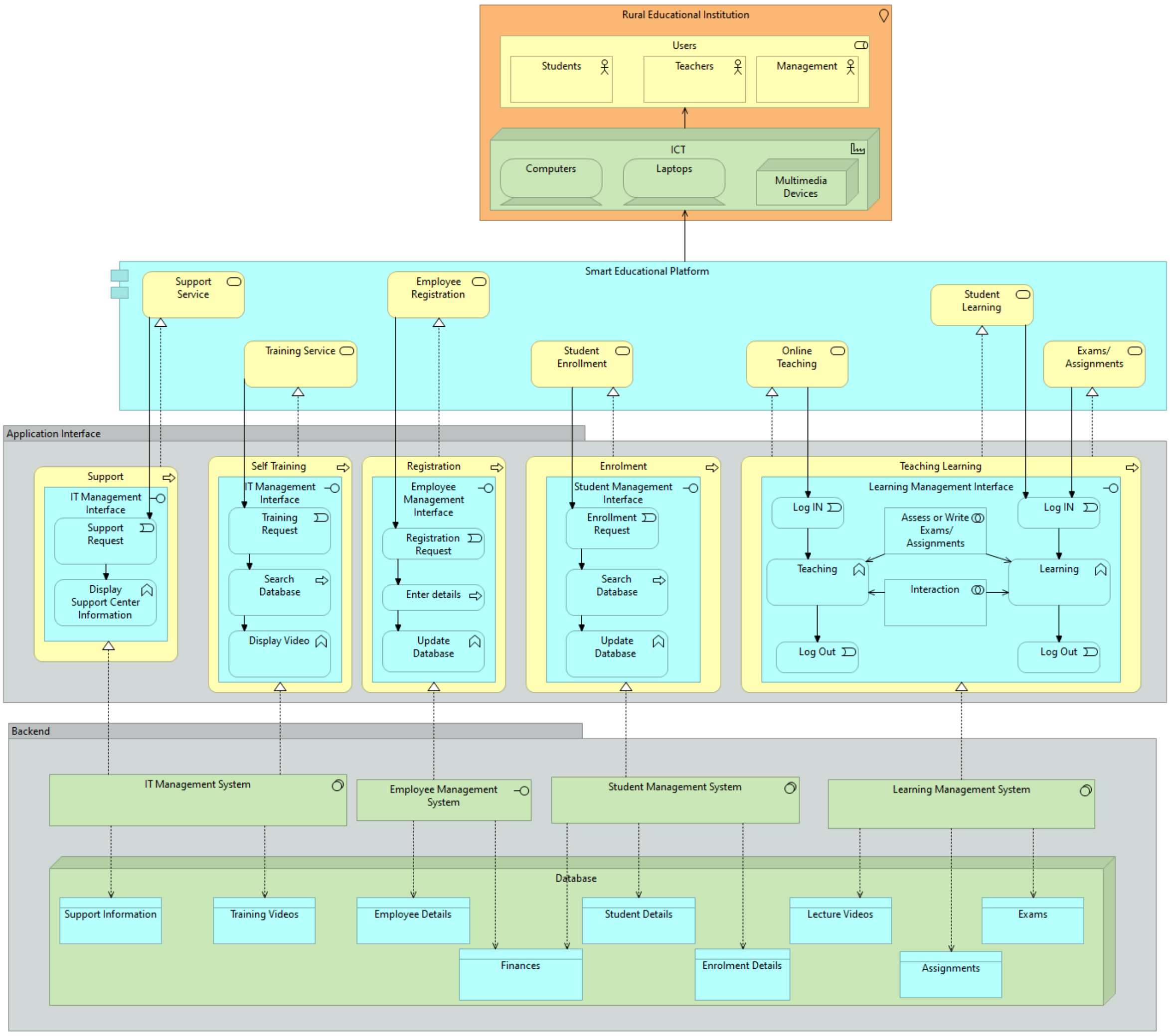

Figure 10: Application Interface Viewpoint

Another process included in this viewpoint is the Teaching-Learning process which describes two services: the learning and exams service. This is intended to support distant education feature that would help save time to travel longer distances during times of unfavourable weather. It is also intended to help save time of teachers on correction of assignments regularly which is time consuming and mundane. The platform is intended to offer auto assessed quizzes or tests. These features of the platform align with the desire of innovating new ways of teaching and learning and sustainability. In the case of an online lecture, the process triggers a “log in” event for both, teachers, and students. This in turn triggers the application function of teaching where the teaching can either do a live session or upload a video. Similarly on the students end they can access the same. And the end of the function triggers a log out event. A similar process work for the exams and assignments service. A collaboration component is provided so that the users can interact during these processes on the platform.

The other components modelled here are the backend components similar to the ICT infrastructure viewpoint. The data objects are accessed by the respective software whenever required.

6.4 Organizational Readiness Viewpoint

As mentioned earlier in the theoretical model, the organizational aspect of smart education is represented by the government. The requirements listed during the literature review also mention a lot about local government involvement and support to facilitate the implementation of such IT platforms (Rahim et al., 2011; Sultana & Sultana, 2010). To add to this, there is evidence that there is lack of implementation policies and strategies (Srinivasan et al., 2013) for the same. Figure 11 represents the architecture for organizational readiness viewpoint. This viewpoint presents an architecture that could address the organizational readiness by assuming roles that create business objects that would help in addressing organizational readiness. Government as role can either be the educational ministers who come up with funding, plans, strategies etc., or it can be the policy makers who make policies to facilitate IT implementation. An Example of such policy is the National Policy on Information Technology that objectifies the utilization of ICT in education sectors in India (Arise, 2021). Various other policies, that will aid the implementation are provision of accreditation certificates, policies for ensuring ICT education are present in the syllabus of high schools, policies that will facilitate easier implementation of IT by getting subsidy benefits, discounts on purchase of devices for education purposes etc. Accreditations help promote schools around the region and makes it popular. Although the government takes up initiatives, it is also the responsibility of the educational institution to come up with regulations that would help and guide the users use the ICT infrastructure efficiently.

On the other hand, government also comes up with strategies that facilitate resource sharing as an initiative (Aldea, Iacob, van Hillegersberg, Quartel, & Franken, 2018) in the direction of smart education. The resource sharing initiative mainly focuses on human resources, IT resources and financial resources. The government also takes up initiatives to design and develop new curriculums that facilitate new teaching-learning methods. The sharing of information and other facilities will be seen in the third-party collaboration viewpoint.

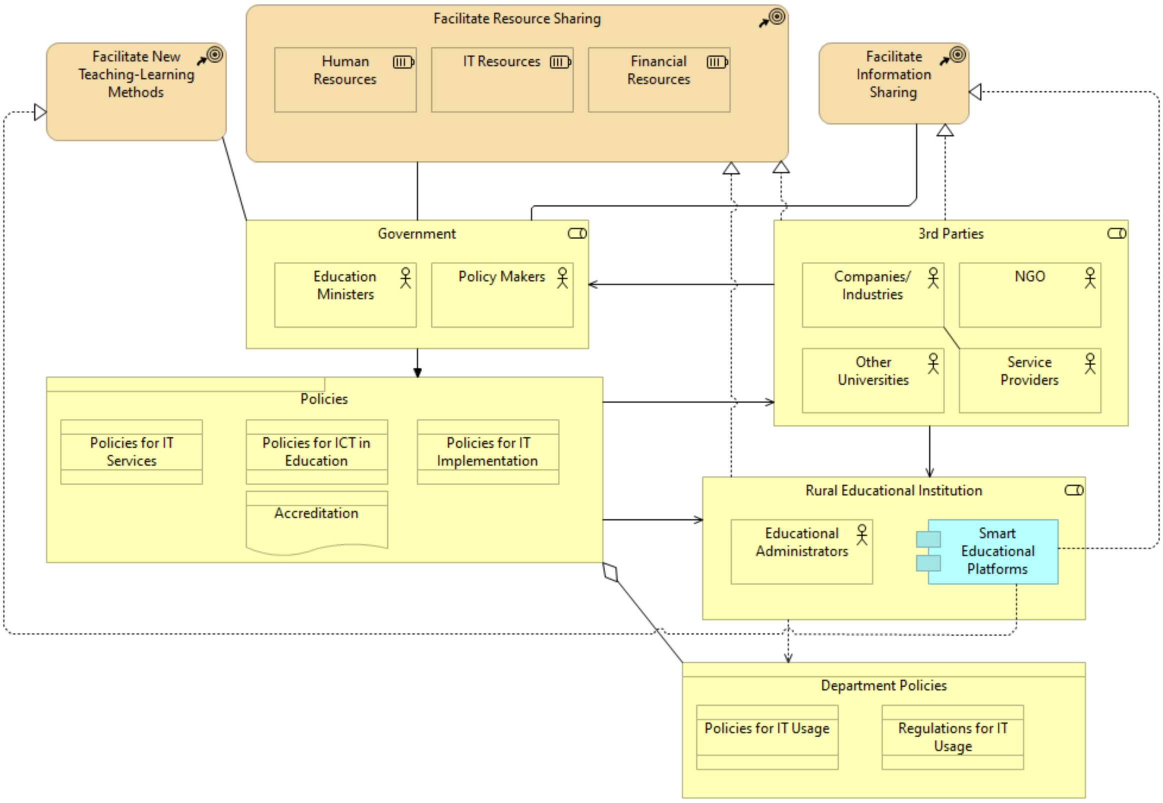

Figure 11: Organizational Readiness Viewpoint

6.5 Training Viewpoint

The users of IT infrastructure in remote and rural regions face challenges in using the system as they lack skills and knowledge on how to use the system (Heinrich et al., 2020). This challenge is noted as a technological readiness factor (TR6). Therefore, the provision of trainings to provide the adequate skills and knowledge is a requirement for the development of such a system. This viewpoint shown in Figure 12 represents the training viewpoint. It has three processes that can be implemented to address the readiness factor (TR6). Here the users of the system are served by the Digital Training service as an additional part of the implementation process. This service consists of three sub-services which are realized as business process individually. An important business role in this viewpoint is of the third parties.

For the realization of introductory training, the service providers are assigned the tasks of provision of manuals and basic videos that will help in understanding the basic use of the system. Universities play a major role in providing the hands-on training of the system use. They can organize workshops, seminars or have small courses that provide knowledge on the use of IT infrastructure which could be accessed by the users of the system. Such collaborations can be established by having a good relationship with the stakeholders or employers of other educational institutions (Asiyai, 2015). Similarly, NGOs can also organize drives or events to help in developing the required skills. Magicbus, eVidhyloka are few among such NGOs that work towards this direction. The Self training service is already described in the earlier viewpoint, which helps the users to watch videos and learn.

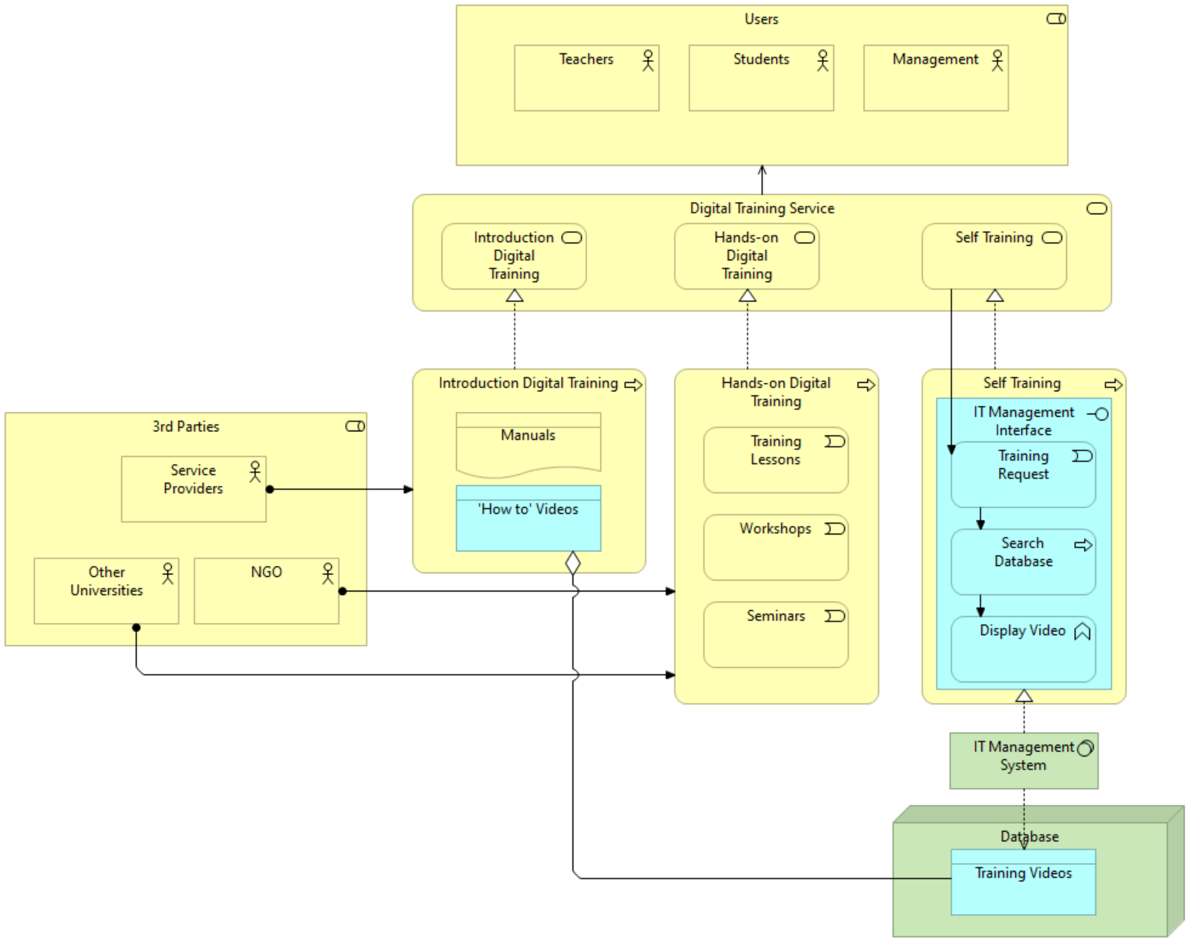

Figure 12: Training Viewpoint

6.6 Third Party Collaboration Viewpoint

As mentioned earlier, there is a need for collaborations from other third parties to realize the implementation of ICT for education in rural and remote regions. The third party collaboration viewpoint represents the collaborations and the benefits of having such collaborations. This can be seen in Figure 13. The important roles in this viewpoint are of the third parties and the users. The government acts as a facilitator to implement policies and other strategies. The initiatives to facilitate resource sharing by the government is realized by the third parties.

The human resource challenge can be realized by the implementation of new policies that would address the rural-urban economic gap by bringing in digital services to the rural regions (Mukti et al., 2021). On the other hand, sharing of IT resources can be addressed in a few ways. During the literature survey for this study, the sharing and re-using of resources is sound to be an important requirement for implementation of ICT in rural regions (Shouyi, Dongling, & Jiajun, 2012). This is seen as an initiative by the government and involves collaborations with mainly large companies/industries and also other large universities. The rural educational institutions can collaborate with industries to utilize their high-tech technologies and to share their expertise to also influence staff trainings (Asiyai, 2015). Industries also play some role in providing IT trainings. E.g., Tata Consultancy Service (TCS) has initiatives to go and teach in the rural regions. Other universities as facilitators of resource sharing participate in sharing facilities, sharing libraries and providing trainings to the users of the system as mentioned earlier. The main focus would be to empower university students (Lo et al., 2016a) who would partake in such implementation projects for either personal or developmental reasons. It is also seen that sharing resources and facilities have high prospects (Anasi & Ali, 2012) especially sharing of libraries. NGOs as business actors conduct educational activities, organize donation drives etc. for the improvement and implementation of ICT in rural regions.

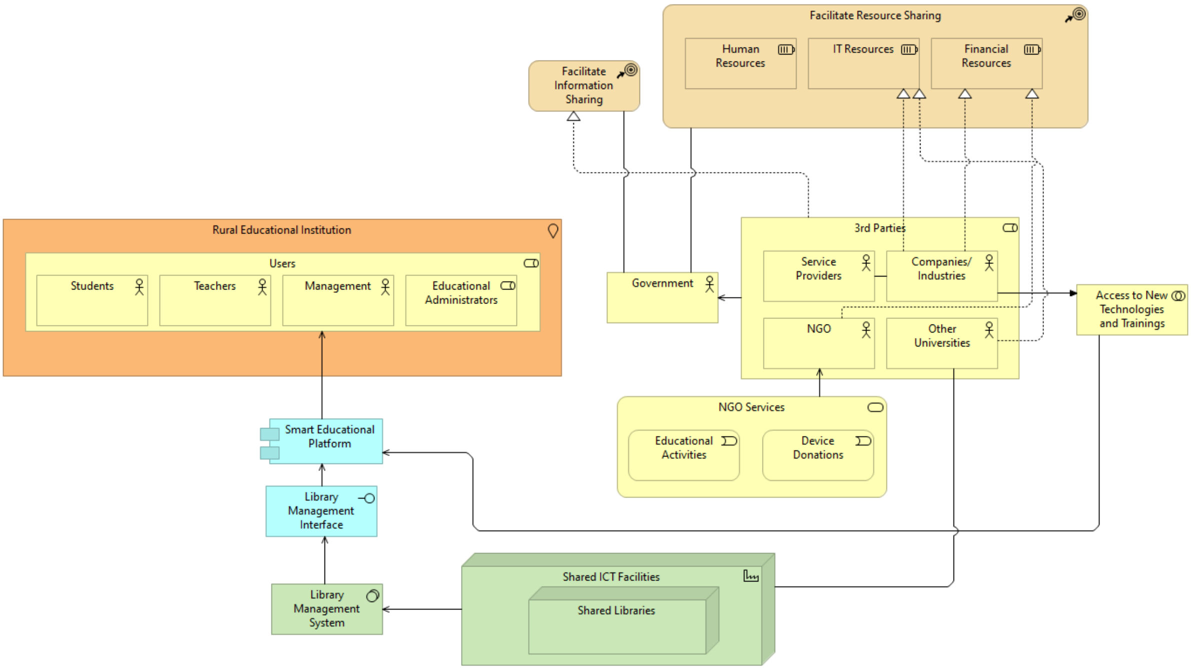

Figure 13: Third Party Collaboration Viewpoint

6.7 Final Architecture Viewpoint

The final reference architecture viewpoint is represented in Figure 14. It depicts the overall abstraction of the smart education system. It consists of a technological layer, a business process layer, a number of business roles, and a strategy component. The technological layer is an abstract representation of the main devices such as the software and hardware devices. They support and run the applications and other interfaces of the application platform for smart education. This platform realizes the business processes of the educational institution. It is to be noted that these processes are not comprehensive, meaning they may differ as per the requirements and organization of different institutions.

The smart education platform focuses on realization of the main processes that are needed to run a high school in a remote and rural location. This includes a support process, a training process, registration process, enrolment process, teaching-learning process. The other processes that are associated with the implementation of smart education are the monitoring and maintenance process and the policy & strategy implementation process.

The users of the educational institute constitute of the students, teachers, management and educational administrators who use the ICT facilities available at the institution and also use mobile devices for the purpose of education. The other business roles represented are the government and third parties composed of industries, NGOs, other universities and service providers. The latter focus on the realization of the business process by being involved in the initiatives and serving their part to facilitate implementing smart education. The government takes up initiatives to come up with policies and facilitate resource sharing for the implementation of smart education in remote and rural regions.

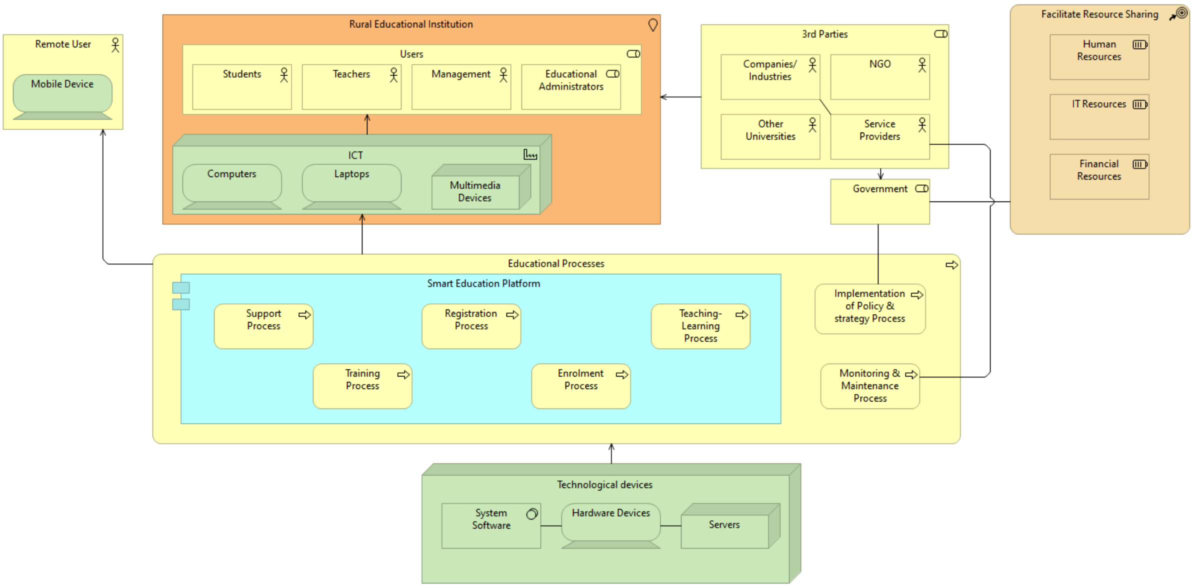

Figure 14: Final Architecture Viewpoint

7. Evaluation of the Proposed Reference IT Architecture

Following the design science cycle of developing an IT artefact, the next step is to evaluate the artefact. Given the scope of this research, only the architecture is developed and not implemented. Hence an evaluation of the correctness of the architecture is not possible. Instead, the goodness of the artefact will be checked by interviewing the end users of the system. This chapter describes the qualitative evaluation of the ICT infrastructure for smart education in rural and remote regions. The evaluation consists of a semi-structured interview and a questionnaire based on UTAUT (Venkatesh, Morris, Davis, & Davis, 2003).

7.1 Using Expert Interviews to evaluate the proposed artefact

A semi-structured interview was conducted to validate the completeness of the architecture. It has been mentioned that semi-structured interviews are the most frequently used for qualitative research evaluation (Crabtree & DiCicco-Bloom, 2006). It is suitable for studying people's perception and opinions (Barriball & White, 1994) even when the interviewees have a low level awareness of the topic (Kallio, Pietilä, Johnson, & Kangasniemi, 2016).

A total of five people were interviewed. The interviewees have different experiences with ICT infrastructure of high schools in remote and rural regions. Three of them have completed a major part of their education in this context and now are IT experts. They are aware of the current scenarios as they volunteer at rural areas for teaching rural kids. Another expert is an IT professor, who studied in a rural region and is well acquainted with the scenario of this study. Another interviewee is a lab technician at a rural college. Having the opinion of these IT experts would be very useful to evaluate the goodness of the architecture.

The questions for this semi-structured interview focused on the variables, indicators and the architecture as a whole. The questions also gathered data on missing elements, or if the elements were wrong. This is beneficial in assessing the appropriateness of the architecture (Kallio et al., 2016). It also gives scope for discussing the relevance of the architecture to a rural context (Barriball & White, 1994).

The interviews were conducted online through Google Meets with a small presentation that included the theoretical model and all the viewpoints of ArchiMate. Firstly, the author gave an introduction of context of this thesis. The goals and motivations were explained next. This was followed by the open-ended questions formulated for this interview. The questions can be found in Appendix D of this thesis.

7.2 Using UTAUT model questionnaire to evaluate the proposed artefact

Although the experts provide insights on the design of the architecture, they are not the end users of the system. The end users are either the students, teachers or management of the educational institution. Therefore, the main aspects such as usefulness, job fit, perceived ease of use and acceptance behaviour will be evaluated by the end users with the help of a questionnaire. The acceptance and use of the model was evaluated using the Unified Theory of Acceptance and Use of Technology's questionnaire (Venkatesh et al., 2003). The UTAUT model helps in understanding the likelihood of success for new technology introductions (Venkatesh et al., 2003). It also considers factors like training that would be needed to facilitate the introductions. UTAUT is targeted at users who are less likely to adopt and use new systems. Therefore, UTAUT is a valid model for understanding the acceptance and behaviour of users of the smart education platform.

The respondents were the teachers who are the end users of the system. The reason they were selected is, this thesis used the data provided by teachers to analyse the theoretical model and that the teachers as mentioned earlier assume different roles in a rural educational context. Hence, they would have the most widened perspective of the usefulness and goodness of the architecture. The questionnaire consists of 4 sections each of which are mapped onto one category of the UTAUT constructs i.e., Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Condition. The performance expectancy is majorly seen as the perceived usefulness of the system, and the job fit which is the capability of the system to enhance the job performance of the user (Venkatesh et al., 2003). The effort expectancy is the perceived ease of use and the complexity factors. Social influence is the social factors for using the system. Finally, the facilitating conditions are the behavioural factors in the environment that help the users to use the system and compatibility. The statements for these were slightly altered to be answered by the respondents. Some statements were not considered as they were not relevant for this study. The questionnaire is available in Appendix E.

7.3 Results of the evaluation

This subsection describes the results of the qualitative evaluation conducted using the earlier discussed methods. First the expert interview results are discussed which is then followed by the results of the UTAUT questionnaire.

7.3.1 Expert Interview Results

Overall, the final artefact was well received by the experts. The final architecture was considered well designed and well developed. There is also some potential to include additional features to it such as security.

Variables and Indicators

The semi-structured interview consisted of questions related to the variables and indicators defined in the model for Smart Education. The experts were questioned if the variables were missing, wrong or were too many or too less. The experts did not find anything missing in the variables and that the variables were satisfactory and sufficient. The indicators were also considered to be well defined and setup for the success of smart education system. One of the experts also thought that provision of funds, human resources and culture and mindset of the people to accept IT were of great importance and their inclusion in the model showed that it is ready for the next step i.e., implementation.

The indicators were also considered well derived but there were two things notable from the evaluation. First, an expert suggested that an indicator for motivation is missing. This is due to the fact that most of the rural students do not continue their studies till the end of a course. 14.9% rural girls in Pakistan drop out of school due to lack of interest (Khan, Azhar, & Shah, 2011). Therefore, an indicator to address this was found to be missing. But it can be argued that the indicator for motivation and mindset are the same. This is because motivation is a characteristic that is influenced by mindset as they are both cognitive processes (Cook & Artino Jr, 2016). Secondly, another expert mentioned that network issues due to heavy rain, flood etc., was found to be missing. Although there was mention of a similar one in technological readiness, an environmental factor in environmental readiness was suggested.

Overall Architecture

The overall architecture was considered to be effective and efficient. The experts did think it would have a positive impact in the rural education sector when implemented. The *smart educational platform* and the *application interface viewpoint* were considered the most accurate ones. Four out of the five experts considered the architecture simple to understand and that it addressed all the requirements of the rural education system. It was also found to be justifiable from a product and value perspective. Teaching, learning and evaluation process are the highest mark carriers for NAAC Accreditation and the experts believe that addressing this process first, enhances the architecture and achieves its main objective. One of the experts mentioned that the architecture would have been judged better with an implementation.

The architecture was also found to have almost all the features required. Some additional features were also suggested by the experts. Firstly, an evaluation system for the delivery of course materials can be added. This is an added feature which helps in understanding the effectiveness of the instructor and the capability of the students to learn from the designed system. A feature to understand and evaluated the effectiveness of the system is needed. Secondly, a security feature for the system was mentioned by a few experts, which could protect the data of the users. Third, an offline method to access the study materials can be added. This is mainly due to the unreliability of internet and electricity in those regions. Fourth, a feature that represents resource re-usability could be added to the architecture. An example of this is, trying to reuse the training materials from previous trainings for new users. Fifth, a feature to track the overall development of students is also an aspect that could be added. Finally, a feature to have more strict supervision while conducting online exams or tests so that malpractice can be avoided.

Practicality for implementation

The final question was related to the practical implementation of a smart education like architecture in the institutions they worked for or were acquainted with. The experts considered that the architecture could definitely be implemented at their organization but mentioned that additional help was required. Financial aid and external help with software integrations were the major concerns for implementation of this architecture. One of the experts also showed concern regarding the scalability. Although the technological elements can be implemented and scaled as required, the trainings and monitoring services when there may be 2000 students and teachers instead of two hundred could cause some issues.

7.3.2 UTAUT Model Questionnaire Results

The results of UTAUT questionnaire are graphically represented here. The overall results are positive. The graphs represent the average scorings of the individual responses. Positive results are seen for perceived usefulness and job fit. This is shown in Figure 15. The questions were targeted at teachers, hence the statements involved questions based on teaching process. The effort expectancy also showed positive results and can be seen with graph in Figure 16. Therefore, the system is perceived to be easy to use and not complex. The social influence factor had a different response. It is graphically represented in Figure 17. It is observed that others using the system does not influence the user to use the system more or less. This shows that the mindset and culture to accept ICT in their educational process is completely independent of social factors. But a facilitating condition for adoption of ICT infrastructure is the organization itself. It is seen that organizations are supportive and facilitate the use of these systems as much as they can. The last factor tested for evaluation is facilitating conditions. The graphs in Figure 18 represent the results for the facilitation condition aspect of the UTAUT model questionnaire. It can interpreted as, even though the system is compatible with all aspects of teaching and learning, there is some gap in existing knowledge and lack of resources on how to use the system. This can be explained by the fact that there is already a gap in the knowledge on ICT usage in rural regions due to lack of resources and infrastructure. Introducing the system in such a setting by providing proper trainings will be a adequate solution to this.

Performance expectancy was measured with two factors from the UTAUT model. The perceived usefulness and job fit. These factors were chosen for the purpose of understanding the goodness of the architecture. To see if the architecture does what it is supposed to do. The end goal of this architecture is to facilitate innovative rural education. Therefore, the questions were aimed at increased resources and improved quality of education indicators.

The effort expectancy questions for this study focused on the perceived ease of use factor from the UTAUT model. The important aspect to remember here is that there is already lack of ICT knowledge in the rural regions. Hence the architecture should be easy to implement and adapt too. Therefore, the aim of the questions was to determine if the architecture as a system was easy to learn and operate.

The mindset and culture are indicators for environmental readiness of the system. The social influence aimed at verifying the same. The organizational support factor can be determined with the statements from social factors of the UTAUT model.

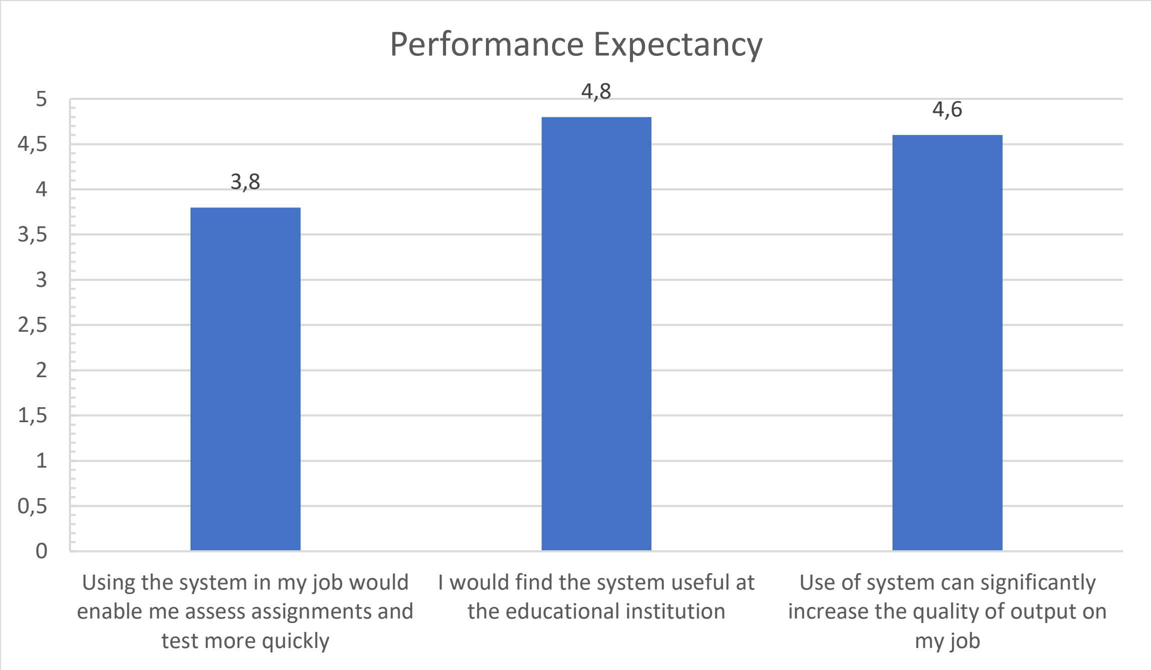

Figure 15: UTAUT Results Performance Expectancy

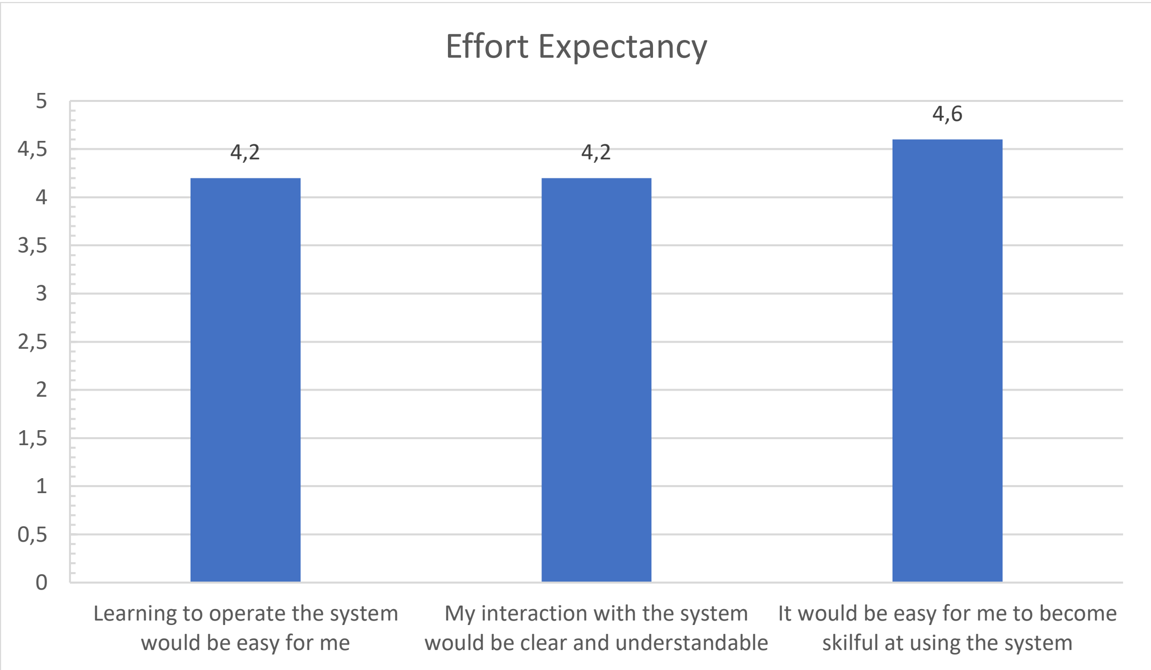

Figure 16: UTAUT Results Effort Expectancy

The facilitating conditions checked the perceived behavioural control, facilitating condition and compatibility from the UTAUT model. The resources and knowledge questions are aimed at existing ICT knowledge of the user's indicator. And the compatibility questions aim is checking if the system addresses all the processes of the educational system.

Overall, the results are considered to be above average and hence shows that the ICT infrastructure architecture serves its purpose well. The evaluations with experts showed that the architecture is well defined and is complete. It can be considered technically fit for implementation. The UTAUT questionnaire results provide evidence that the architecture for Smart Education is also goodness compliant meaning to say it is useful, easy to use and system compatible for a rural education scenario.

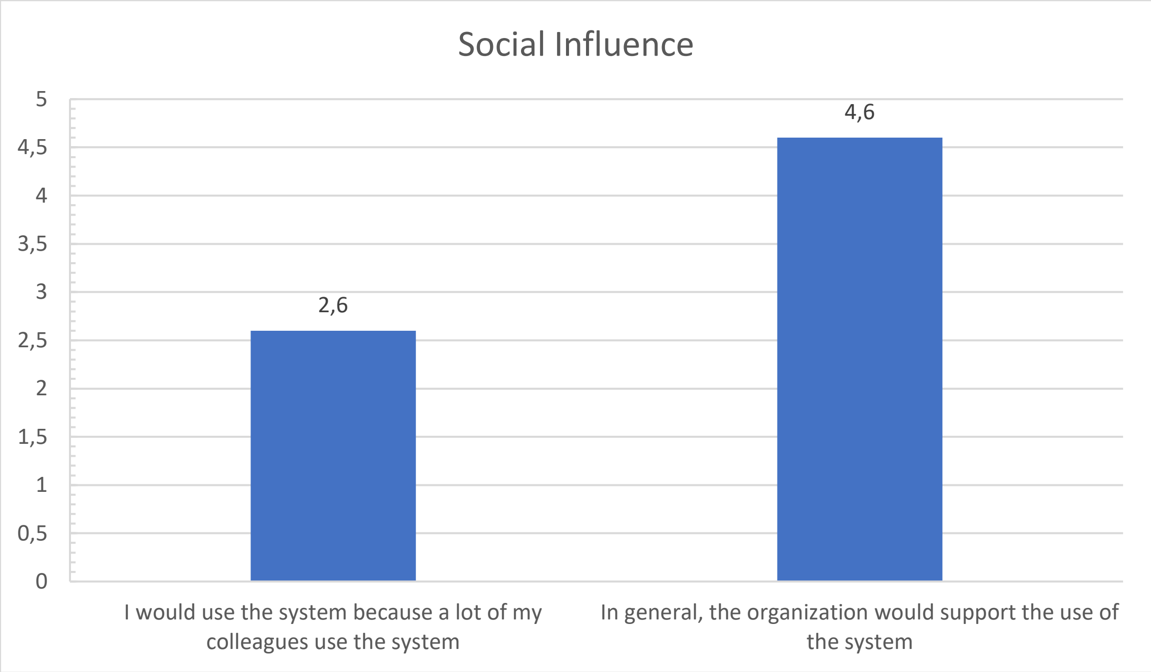

Figure 17: UTAUT Results Social Influence

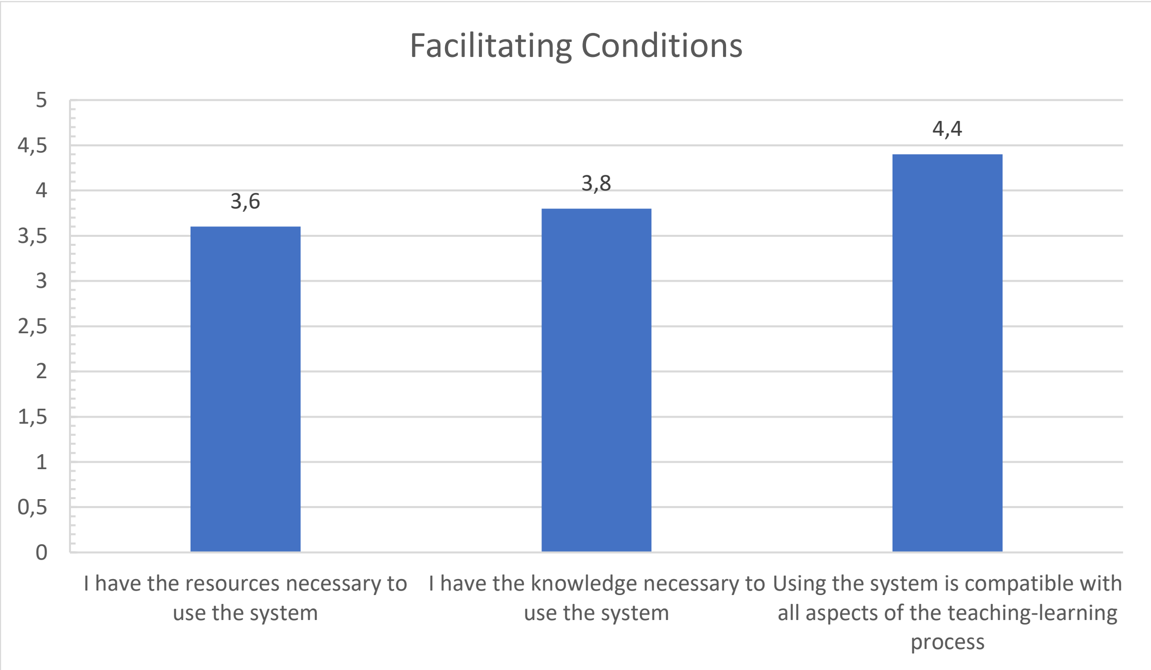

Figure 18: UTAUT Results Facilitating Conditions

7.4 Limitations of the Evaluation Study

This section discusses the limitations of evaluation. Firstly, the number of respondents who participated in the evaluation of the architecture is limited. This limitation results in gathering of limited opinions. The expert review and the UTAUT questionnaire could have more respondents which helps to evaluate the architecture thoroughly. Secondly, it can be considered a limitation that the experts are acquainted with only a particular rural area. The practitioners who answered the UTAUT model-based questionnaire are only teachers who work in an educational institution of the rural sector. This sets the limitation for claiming universal generalizability (Ghaisas, Rose, Daneva, Sikkel, & Wieringa, 2013). This raises the question whether similar findings can be observed if other experts are interviewed, and other practitioners such as students or people from the management answer the questionnaire. Although universal generalizability cannot be claimed here, based on the theoretical foundation and research methods used for this thesis, it might be possible to have similar observations when respondents who work in similar educational institutions, with similar educational processes and use similar ICT infrastructure evaluate the reference IT architecture.

8. Conclusion

As stated in the initial pages of this research, although there have been initiatives to make education accessible to everyone, the type of education each individual receives is not the same. The students living in the urban areas have better opportunities due to the presence of IT in their educational processes is a proven fact. This has not only affected the rural education sector but has also led to a variety of other issues in the rural areas. These mainly include lack of transportation facilities, lack of IT services and majorly migration from rural to urban areas. Hence it is important to come up with a smart education system in these areas that would help include IT in the educational processes of the users and give them better accessibility and opportunities to a wide range of information.

The main objective of this thesis is to propose a reference IT architecture to facilitate implementation of smart education in the context of rural and remote regions. The reference architecture proposed consists of a motivation viewpoint, an ICT infrastructure viewpoint, an application interface viewpoint, an organizational readiness viewpoint, a training viewpoint, third party collaboration viewpoint and a final architecture viewpoint.

The overall methodology of this research is as described in Chapter 2. First a problem context was investigated which led to the formation of research questions. Following which a systematic literature review was conducted to know the state-of-the-art which provided a list of challenges, available solutions, and requirements for ICT implementation in rural and remote regions. This helped in development of the theoretical model for predicting the adoption of Smart Education based on the principles of Rural Smartness by (Mukti et al., 2022). This step is the empirical research method where several hypotheses were formulated. These were then tested by gathering data to check the correctness of the hypotheses, which entailed quantitative validation using PLS-PM with ADANCO.

The design science cycle consists of problem investigation which was done earlier. The treatment design task consisted of translating the emergent variables of the theoretical model as requirements to further develop the reference architecture which is the artefact. This design is validated by expert interviews that checked for the completeness of the architecture and also UTAUT questionnaire which verified if the model was useful from a user's perspective.

8.1 Answer to the Research Questions

RQ1: What is the state-of-the-art of IT in high schools of rural and remote regions?

A systematic literature review is performed to discover the current state-of-the-art for IT in rural and remote regions. Relevant scientific journals and articles that fit the context of the study are reviewed. The literature review mainly focuses on the challenges to implement IT, the available IT solutions in the rural and remote regions and the requirements that aid in IT implementations in remote and rural regions. The literature review produced the following results. Firstly, the challenges could be categorised and focused on technological, environmental, locational and societal aspects. The locational and societal aspects are equivalent to organizational aspects. The biggest challenges were lack of resources, lack of financial aid and lack of IT knowledge/skills. The main reason for this is the geographical location being isolated and dispersed. Environmentally these regions are also prone to floods and other extreme weather conditions. These lead to lack of resources including human resources due to urban migration. Lack of resources leads hinders the opportunities for low-income people to access these technologies resulting in low IT knowledge.

Next, the available solutions would be the presence of a few architecture frameworks. These have the ability to start some new implementations. Although these are theoretical solutions, mobile technologies are the technologically available solutions for ICT implementations. Mobile devices are low cost, largely available and portable. Hence this makes it an ideal device for ICT implementation. Photovoltaic cells are the energy supply solutions. Notables large number of e-learning opportunities happened with the presence of energy supply from PV cells integrated with IoT.

Finally the requirements of ICT implementations focused on IT service, which includes the supply of ICT devices, software, hardware, internet and other infrastructure. Presence of technical support is also notably mentioned a lot in literature. The involvement of third parties such as local and federal governments, NGOs, industries and other universities also have a bigger hand at improving the life of remote communities than any other person. The ICT infrastructure should be easy to use and implement.

RQ2: What are the factors that impact the adoption of smart education in high schools of remote and rural areas?

This thesis formulated an original model for predicting the adoption of smart education in high schools of rural and remote regions. The model represents the readiness factors that influence the adoption of smart education in high schools of remote and rural regions. Technological readiness, Organizational readiness and Environmental readiness are the three factors that influence the adoption of smart education. The factors also consist of indicators that help to measure their readiness. The implication of having smart education is innovative rural education. Smart education is considered as an educational aspect of rural smartness. Therefore, the theoretical model for predicting the adoption of smart education is based on the rural smartness principle. Based on this, a few hypotheses are formulated, and the findings are presented. These findings describe how, and which factors influence the adoption of smart education.

First, technological readiness is found to have a strong and direct effect on environmental readiness. It does not have a direct contribution on the realization of smart education. This statement provides evidence that mere presence of technological devices does not help in realizing smart education. It is also important to have the mindset to accept these devices and use them for the right purposes. Second, organizational readiness has moderate positive effect on technological and environmental readiness. It also does not have a direct effect on the realization of smart education. Government as an organization has a major role to play when it comes to ICT adoption in rural areas. Government can influence the technological readiness by bringing in more services and ensuring better service provision. Similarly, government and organization influences the culture and mindset and also helps in forming regulations for adoption of smart education. Third, environmental readiness has a strong positive influence on the realization of smart education. This proves that culture and mindset is required to accept a new technology, along with some knowledge on how to use the system and regulations to use it. The adoption is also facilitated with the help and involvement of third parties who provide various resources and services for the realization of the same. Finally, smart education has a strong positive effect in innovative rural education. Education in the rural region can be influenced by including ICT. It helps not only to increase resources but also to improve the quality of education provided.

RQ3: What is the reference IT architecture for implementing smart education in remote and rural regions?

The final reference architecture is derived by translating the emergent variables into functional requirements for developing the artefact. These variables are represented as requirement components in the motivational viewpoint (Figure 8). These requirements are then translated into individual services. The ICT infrastructure viewpoint (Figure 9) represents the physical elements and their application interfaces. These help to realize the services that smart education is supposed to provide. The viewpoint also represents the various actors who are the end users of the system. This viewpoint also addresses the monitoring and maintenance service by assigning the service to the service providers. The basic processes which are in the educational context are modelled in the Application interface viewpoint (Figure 10). The viewpoint also shows the basic internal functions of the process. This viewpoint is an elaborated version of the smart education platform designed in the ICT infrastructure viewpoint. The organizational readiness viewpoint as the name describes addresses the organizational readiness elements. The government as a business role introduces policies and implements them. The educational institute is aggregated of these policies plus the regulations on the usage of IT. The government also strategizes to facilitate sharing of resources and other information by involving and collaborating with third parties. The training viewpoint (Figure 12) addresses the requirement for the same. It also helps in acquiring knowledge on the use of ICT. The viewpoint represents the users and the training providers. The service providers provide basic training whereas the third parties provide improved and elaborate trainings on how to use the system. The third-party collaboration viewpoint (Figure 13) represents how the collaborating can be facilitated between the government, educational institution and third parties. The main benefits of this would be access to new technologies through industries, access to IT resources through industries and other universities and access to funding and other donations through NGOs. The collaborations also help in improving training services as mentioned earlier. The final architecture as represented in the viewpoint (Figure 14) depicts the main actors involved, the basic technologies required and the minimum number of processes to be addresses while designing and implementing smart education in rural and remote regions.

RQ4: Does the architecture serve its purpose? Is it complete and useful?

To answer this final question, the validation of the artefact was done using two methods. An expert interview is conducted to check the completeness and a UTAUT model-based questionnaire is sent to the end users of the system to validate if it is useful from their perspective.

The overall architecture was evaluated by the experts. All the variables in the model are found to be justified and sufficient. Although an indicator for motivation is found to be missing, it can be argued that motivation is a psychological element and is connected to the mindset and culture indicator. The overall architecture is found to be efficient and effective. The architecture also addresses the main functions that are required for a teaching and learning process. Some suggestions for additional features are made. This mainly includes a function that evaluates the development of the student, and a feature that provides a strict supervision during online exams. The feature found to be missing was related to security. Nevertheless, the architecture is found to be practical for implementations as it is found to be easy to understand.

The results of the UTAUT questionnaire also had overall positive results. The performance expectancy was evaluated to check the usefulness of the architecture. The results showed that the system serves its purpose from a user's point of view. The effort expectancy also showed positive results. This indicated that the system was easy to use. The social influence factors showed that use of ICT by others did not influence the users to use the system more or less. In the facilitating conditions factor, it is observed that a little more training and resources to support the use of the system is required. Finally, the overall system is found to be compatible with all aspects of teaching-learning process. Hence it is considered easy to use, useful and job-fit.

8.2 Contributions and Implications

This thesis made two original contributions. First the theoretical model for predicting the adoption of smart education in rural and remote regions. Second the reference IT architecture for facilitating the implementation of Smart Education in rural and remote regions. The first contribution included a thorough systematic literature review in the field of ICT implementation in rural and remote regions. This identified the challenges, available solutions and requirements for ICT implementations leading to identifying the state-of-the art in the given problem context. The empirical research method helped in producing the first contribution which is the theoretical model for smart education. This included the empirical validation of the model too. The second contribution is the reference IT architecture which is the artefact of this thesis. Design science cycle not only guided the development of this artefact but also aided a qualitative evaluation of it. This section further elaborates on the contributions and implications of this thesis.

The biggest problems faced during the pandemic by school students of rural and remote areas related to ICT infrastructure. The students were not able to access online classes or any other educational resources mainly due to the lack of such infrastructure. Previous research also showed that there is a huge gap in the ICT knowledge of rural and urban students (R.-S. Chen & Liu, 2013). One of the solutions to tackle this gap is to provide the rural students with the resources and infrastructure they need to bridge this gap. The teachers of these regions also need to use the required ICT to teach the same to the students which can be done by implementing basic ICT infrastructure in the schools of remote and rural regions. This is a daunting process and needs a lot of aspects to be addressed. There have been multiple researchers that contributed towards this direction by developing frameworks (Rahim et al., 2011), by implementing programs with make shift ICT facilities (Diniz et al., 2006; Hossain & Fatemi, 2009), studying the factors that interact with educational technologies (Heinrich et al., 2020), etc. However, there are very few studies that focused on developing a complete reference architecture that will act as a methodology for implementing ICT in rural and remote regions education sector. The R^2 value obtained through PLS-PM provides evidence for the same.

Given this evidence, the practical contribution of this research can be listed as follows. Firstly, the theoretical model acts as a base work that can be used to assess the readiness factors for implementation projects that are related to ICT and education as this model has been validated quantitatively and hence provides sufficient evidence that the model is tried and tested. The architecture developed acts as a guideline architecture that can be used by researchers and practitioners to design smart education like systems, e-learning systems and other ICT inclusive educational systems for rural and remote regions. This is also evaluated to be useful and complete by end users and experts. Therefore, the processes, components and interactions defined in the architecture can be considered as minimum requirements for developing such a system. The architecture is designed using a modelling tool Archi that uses ArchiMate modelling language. For future research, this architecture can be referenced for representations of various views, their elements and their relationships in modelling of real-world architectures of similar contexts. Finally, the research as a whole provides a framework on how to initiate ICT implementation projects in rural and remote regions.

8.3 Limitations and Future Research

There are a few limitations identified in this research. The number of respondents who participated in the validation of the architecture is limited. This limitation results in gathering of limited opinions. The expert review and the UTAUT questionnaire could have more respondents which helps to validate the architecture thoroughly. The limitation for claiming universal generalizability is also seen. The next limitation is that the architecture lacks a viewpoint for funding. There are two reasons for this; first, provision of funds as an indicator did not have loadings as much as expected. Second, when the context of a rural education sector is considered, the funding service only happens through the government and needs to be addressed by the government. Therefore, the funding is seen as a resource sharing strategy element rather than an entire viewpoint. The next limitation is that the research only translated the data gathered during the systematic literature review to model the theoretical model and the architecture. Therefore, the limitations of the systematic literature review apply, such as missing certain articles that could have been more relevant. Final limitation is that the architecture has not be implemented in a real case. That is, it has not been tested and validated post implementation. Hence the usefulness and goodness are only based on literature, user and expert opinions. A validation post implementation may reveal limitations unknown to this research.

The last limitation paves the way for future research. Therefore, for future work this reference architecture could be implemented in a real case scenario. A real implementation would open new research opportunities in the direction of ICT infrastructure implementation. Another scope for future research is in the direction of Smart Education. The low R^2 Value presented low research in this area. Therefore, researchers can take up interest and develop new models and architectures for smart education. Finally, more research in general can be carried out in the direction of rural education sectors. Although there has been a lot of research proceeding towards rural topics, it is not enough, especially in the context of developing countries there is a huge gap in knowledge and resources.

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Appendix A: Articles used in Systematic Literature Review

No.	Reference	Research Purpose
P1	(Diniz et al., 2006)	"This paper describes Brazil's photovoltaic rural school electrification program developed in the southeastern state of Minas Gerais, from its demonstration phase through its current larger-scale (near 1000 systems) deployment."
P2	(Rahman, 2007)	"This paper will try to synthesize various indices of e-Government readiness and derive general recommendations on successful implementation of e-Government systems across the world."
P3	(S. Al sayed, 2008; S. A. Sayed & Al-Rouh, 2008)	"The main aim is to facilitate accessibility of ICTs for all, and how to bring about necessary conditions for PWDs…"
P4	(Hossain & Fatemi, 2009)	"Promoting 'Off the Grid' school: Application of RET to develop educational infrastructure in Bangladesh"
P5	(Luk et al., 2009)	"The main contribution of this paper is to reflect on some ways in which the context and background of researchers affect the structure of ICTD projects. A second contribution is in identifying relevant factors which will assist in the design and execution of ICTD projects in the future"
P6	(Sharma et al., 2009)	"In this paper, we propose Cell-Share – an architecture that leverages the growing trend in mobile phone coverage throughout the world augment rural WiFi mesh networks"
P7	(Suhardi & Wulandari, 2009)	"Case study is carried out at the village Cinta Mekar – Subang (West Java) to support Indonesian Government program in providing IT and Telecommunication services at affordable cost"
P8	(Sultana & Sultana, 2010)	"In this paper we propose to design a web service oriented resource based system named "E-School" for the primary, secondary, and higher secondary education system of Bangladesh"

P9	(Rahim et al., 2011)	"The research aims to implement ICT in education to improve the quality, which provides the basic education for all students by the introduction of emerging teaching, learning tactics with new methodologies with emerging technologies"
P10	(Widyani, Langi, & Putri Saptawati, 2011)	"This paper describes an architectural design of a Digital Learning Product Service System (DL-PSS). Consisting of products and services, the DL-PSS includes (i) ICT infrastructures and their operational services, (ii) software products and their operational services, (iii) education programs and their implementation services,…"
P11	(Shouyi et al., 2012)	"In recent years, although it has made some achievements, there still exists the problem, such as, the laggard concept, insufficient capital and infrastructure, invalid policy. For promoting the healthy and steady rural education information technology development, we should renew the idea, increase capital input and infrastructure construction"
P12	(Srinivasan et al., 2013)	"In this paper, we present an inoculated combination of technologies to facilitate and advocate education in Rural India"
P13	(De La Concepcion et al., 2014)	"In this paper we give an overview on the project for implementing a low cost wireless communication network over the three islands of Comoros, which helps overcoming the major infrastructure limitations,…"
P14	(Munkhtsetseg et al., 2014)	"This paper describes the selection and implementation of the e-learning system at the school of mathematics and computer science, national university of mongolia (num)."
P15	(Lu et al., 2015)	"This paper reports a survey conducted on the infrastructure and application of ICT in middle and primary schools in urban areas (city and county) and rural areas in China based on their demands for promoting ICT in education"

P16	(Segooa & Kalema, 2015)	"This study aims to present contextualized VLE model for education institutions in developing countries by taking a case of a higher institution of learning in South Africa"
P17	(Selviandro et al., 2015)	".. in practice there are still some obstacles, such as learning resources are not evenly distributed, limited access to services provided, qualified educators resources are concentrated in specific areas. This led to the emergence of disparities educational process, and technology gap due to differences in ICT infrastructure owned by any educational institution. Therefore this study proposes architecture of cloud-based open learning to solve these problems"
P18	(Lo et al., 2016a)	"This project seeks to investigate how education in developing countries may be supported through appropriate ICT technology"
P19	(Nainggolan et al., 2016)	"This paper explains the design and implementation of a videoconference system, along with its supporting operating system, applications and hardware."
P20	(Kaliisa & Picard, 2017)	"The purpose of this systematic review is to analyse published studies focusing on mobile learning in higher education within Africa"
P21	(Mufeti & Sverdlik, 2017)	"This paper contributes to the research whose main objective is to seek models and examples of good practice in the introduction of Computational Thinking and Problem Solving skills in secondary schools in developing contexts. The paper will use the NAMTOSS initiative as a case study to identify the critical success factors as well as the challenges that are imminent in such initiatives"
P22	(Tabira & Otieno, 2017)	"By designing appropriate methods, this paper also clarifies the barriers to diffusion of ICT in education"
P23	(Ahmed et al., 2018)	"This paper is study about the status of e-learning in developing countries, taking Pakistan as a case study. The objective is to explore the factors that influence the adoption of e-learning in an ODL institution of Pakistan"

P24	(Talusan et al., 2018)	"In this paper we introduce a cloudless platform for rural areas, Near Cloud."
P25	(Tom et al., 2019)	"This study sought to explore the factors that influence the adoption of cloud computing for e-learning by amalgamating the Diffusion of Innovation as well as the Technological, Organizational, Environmental theory"
P26	(Bishnoi & Suraj, 2020)	"This study examines the issues, challenges, constraints and the implications of technology intervened remotely conducted online examinations in India.."
P27	(Heinrich et al., 2020)	"This study investigates how pedagogical, cultural and institutional factors interact with technical knowledge in educational technology integration and how they relate to equitable and effective technology use in low-resource settings"
P28	(Owen et al., 2020)	"e. This study investigates issues for implementing ICT in schools in relation to teacher and school leader attitudes, access and ICT use, and improvements needed in Papua which is one of the most remote regions of Indonesia"
P29	(Pham, Dao, Nguyen-Thanh, Cho, & Pham, 2021)	"this paper proposes an adaptive SES framework, named vSmartEdu, which was built by adopting a service-based architecture (SBA) design to develop smart classrooms"
P30	(Svetsky et al., 2021)	"This paper describes the progress that has been made in research on the ICT support for teaching processes, … with a particular focus on the development of the personalized educational software"

Appendix B: Survey Questions

Technological readiness

1) Internet Access
    1. There is proper internet access already established at the educational institution.
    2. There is proper internet access available at home.
2) Stable Electricity
    3. Electricity is always available in the educational institution to access IT services.
3) IT infrastructure accessibility and availability
    4. IT devices such as mobiles, computers, laptops, routers, hardware materials etc. are easily accessible (able to easily get it without travelling very far) for educational use.
    5. IT devices mentioned above are available at the educational institution location.
4) IT Service Provisioning
    6. There is sufficient number of service providers (for internet, device installations etc) in the region of your residence.
    7. The provided IT service is suitable for educational purposes.
5) Monitoring and Maintenance
    8. There is help available immediately when there is something wrong with the IT systems.
    9. There is regular maintenance of the IT systems.
6) Training support
    10. There is training provided on the use of IT devices for educational purpose (E.g.: Conducting online classes, online examinations).

Organizational Readiness

1) Provision of Funds
    11. The government is providing financial funding for implementing IT infrastructure in the area.
2) Human Resource Support
    12. There is a balanced teacher-to-student ratio in the educational institution.
3) Strategies for IT Implementation
    13. There have been initiatives and programs from the government on IT implementation (such as BSNL Air Fibre, PM WANI, provision of electricity, etc).
4) Collaborations with private sectors
    14. The government is collaborating with private sectors (such as broadband providers, HESCOM, TELECOM, Airtel, BSNL etc) to facilitate the usage of IT services in the area.
5) Policy making strategy

15. The government is making policies (such as reduced internet costs, reduced electricity costs, subsidy for IT device purchasing in large scale) that will facilitate the usage of IT services in the area.

Environmental Readiness

1) Culture and Mindset
   16. You are voluntarily willing to use IT infrastructure for educational purposes.
2) Existing IT knowledge
   17. You have enough knowledge to use IT for educational purposes.
   18. You understand how IT supports the educational tasks you are involved in.
3) 3rd party involvement
   19. There are many 3rd parties (such as NGOs, clubs) that are involved to a large extent in the provision of IT services.
4) Departmental Policies
   20. There have been guidelines and policies provided by the department/educational institution on how to use IT infrastructure for educational purposes.

Smart Education

1) Information flow
   21. The educational institution is able to exchange information among the different departments using IT infrastructure.
   22. The teaching-learning process uses IT infrastructure for most of the activities (exams, lectures).
2) Collaborative Governance
   23. The teachers and students are able to actively participate in the initiatives (that smart education would provide) to improve their welfare (in terms of education) due to the availability and usage of IT services.
3) Digitally skilled users
   24. The users of IT for educational purposes are able to access broader information due to the presence of IT infrastructure.
   25. Students have better opportunities due to the presence of IT in education
4) Coherence of IT service
   26. There is a clear strategy from the government for the provision of coherent (uninterrupted) IT services.

Innovativeness

1) Increased use of remote communication
   27. The provided IT infrastructure has increased the use of remote communication for educational purposes.
2) Improved collaborations

28. The provided IT infrastructure has improved the student-teacher and student-student collaborations.

3) New methods of teaching-learning

29. The provided IT infrastructure has fostered the use of innovative methods for teaching-learning.

Perceived usefulness

1) Increased resources

30. The presence of Smart Education increases the resources for educational purposes.

2) Improved quality of education

31. The presence of Smart Education improves the quality of education in one way or the other.

3) Sustainability

32. The presence of Smart Education saves time and energy spent on accessing the resources for educational purpose (E.g., travelling to find network, travelling to find a laptop).

4) Increased ICT knowledge

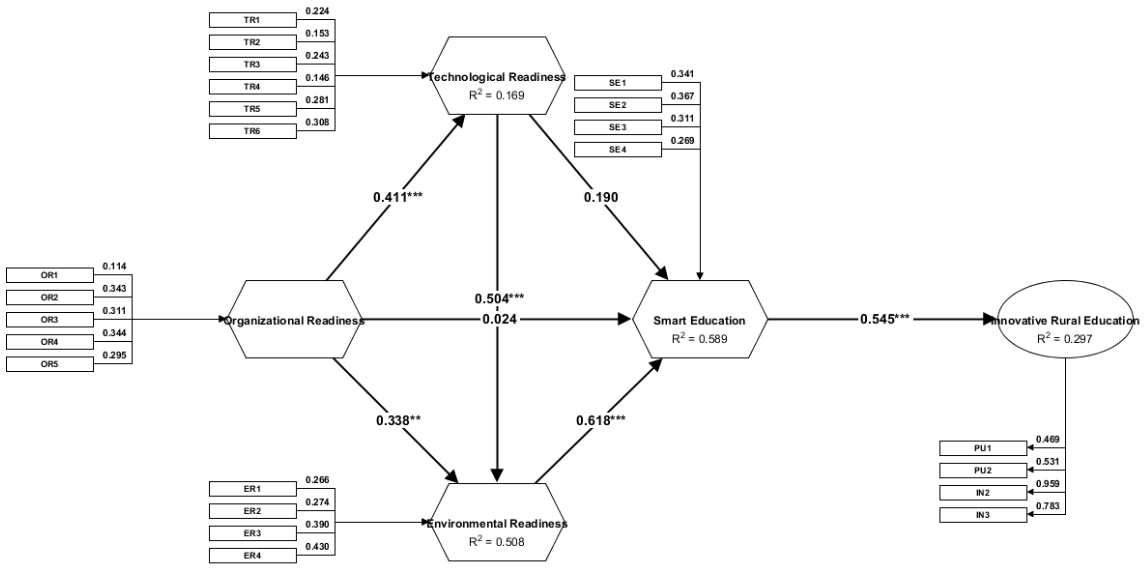
33. The presence of Smart Education leads to an increase in knowledge of IT and its use.

5) Improved accessibility and availability

34. The presence of Smart Education improves the accessibility (reaching or obtaining) for IT infrastructure.
35. The presence of Smart Education improves the availability of IT infrastructure

Appendix C: ADANCO Graphical Representation of the Model

Graphical representation of the model



Appendix D: Expert Interview Questions

1. What is your Job?

2. What is your opinion on the model for Smart Education? Do you think its justifiable?

3. What is your opinion on the architecture of Smart Education?

4. Do you think a system like Smart Education can be implemented at your educational institution?

Variables (TR, OR, ER, SE)

1. What do you think of the Identified Variables?

2. Are some missing?

3. Are some wrong?

4. Are there too many or too less?

Indicators for the variables

1. What do you think of the Identified Indicators?

2. Are some missing?

3. Are some wrong?

4. Are there too many or too less?

Smart education architecture:

1. What do you think of the designed architecture?

2. Do you think it covers all the aspects that would be required for such a system?

3. Do you think the most important processes of an educational institute are covered in the architecture?

4. What other features could be included?

Appendix E: UTAUT Questionnaire

Factors	Original UTAUT statement	Adapted UTAUT statement
Performance Expectancy	1. Using the system in my job would enable me to accomplish tasks more quickly	1. Using the system in my job would enable me assess assignments and test more quickly
	2. I would find the system useful in my job	2. I would find the system useful at the educational institution
	3. Use of system can increase the quantity of output for the same amount of effort	3. Use of system can significantly increase the quality of output on my job
Effort expectancy	1. Learning to operate the system would be easy for me	1. Learning to operate the system would be easy for me
	2. My interaction with the system would be clear and understandable	2. My interaction with the system would be clear and understandable
	3. It would be easy for me to become skilful at using the system	3. It would be easy for me to become skilful at using the system
Social Influence	1. I use the system because of the proportion of coworkers who use the system.	1. I would use the system because a lot of my colleagues use the system
	2. In general, the organization has supported the use of the system.	2. In general, the organization would support the use of the system.
Facilitating Conditions	1. I have the resources necessary to use the system.	1. I have the resources necessary to use the system. Eg: User Manuals, devices etc
	2. I have the knowledge necessary to use the system.	2. I have the knowledge necessary to use the system. Eg: Trainings
	3. Using the system is compatible with all aspects of my work.	3. Using the system is compatible with all aspects of the teaching-learning process