

## **Principal Component Analysis of ICT Adoption Among Students in Developing Countries**

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**Abstract** Integrating Information and Communication Technology (ICT) in educational settings has become fundamental to modern pedagogy. Despite its significant contributions, ICT's adoption, integration, and usability pose challenges for school students in developing countries, particularly in Sub-Saharan Africa. This study aims to identify and analyze the diverse factors influencing the widespread adoption of ICT among students. A comprehensive systematic literature review revealed 38 factors from 84 articles that either facilitate or hinder ICT integration in students' academic activities. Using Principal Component Analysis (PCA) a statistical method known for reducing dimensionality and uncovering patterns in complex datasets. The study extracts the most critical factors impacting ICT adoption. The findings indicate that in addition to over-digitalization, cognitive barriers, health issues, time constraints, funding limitations, and a lack of modern software are significant factors affecting students' engagement with technology. The implications of this study are relevant to policymakers, educators, and academic institutions, providing a data-driven basis for strategies aimed at improving ICT adoption.

**Keywords:** Digital literacy · Developing countries · ICT adoption · Principal component analysis

## 1 Introduction

Information and Communication Technology (ICT) has been widely introduced in schools for students to learn. According to the literature, teachers in rural secondary schools are jumbled about ICT adoption, integration, and usability to facilitate studies and educational practice [1–3]. This lack of clarity about ICT adoption, integration, and usability in schools can wreak havoc on students and lead to a heightened digital divide.

The challenges of implementing ICT in developing nations are well-documented as noted by Diaz et al. in [4], the prevalent issue of home connectivity, raises significant concerns. Despite the recognized benefits of ICT in education and domestic settings, resistance to widespread adoption in rural secondary schools is largely attributed to a variety of deterrents such as According to [5], rural secondary schools lack necessary ICT infrastructure. Additionally, a shortage of ICT skills [6] and a dearth of trained instructors [7] have been identified as persistent challenges. Given the benefits of ICT, there is a significant research gap in addressing its adoption among rural secondary students in developing countries, which this study seeks to fill by highlighting more persuasive factors influencing ICT adoption. Mhlana, Chipangura and Twinomurinzi [8] identified this oversight by observing that most studies have focused on developed rather than developing countries.

These issues underscore the urgent need for this systematic review, which seeks to reconcile the disparities between developing and more developed countries in terms of ICT adoption. Thus, this study's primary objective is to ascertain the critical factors impeding the broad acceptance of ICT among rural secondary students in developing countries. The study conducted a comprehensive systematic literature review to analyze, discuss, and identify significant factors. Section 2 covers background and related works, Sect. 3 outlines the materials and methods, Sect. 4 presents the result analysis, and Sect. 5 concludes the study based on the findings.

## 2 Related Work

The Fourth Industrial Revolution (4IR) has significantly impacted the design and delivery of Basic Education (BE), especially with the integration of Information and Communication Technology (ICT). However, this transformation has been uneven globally. While Western and Northern developed regions have adapted more seamlessly, Sub-Saharan Africa (SSA), including countries like Botswana, South Africa, and Ethiopia, faces distinct challenges in ICT integration, particularly in junior secondary schools. Siamisang et al. [9] emphasize challenges including lack of ICT skills, confidence in technology, and inadequate technology devices in schools.

Despite the slow progress, the potential of ICT in revolutionizing education and alleviating poverty is undeniable. However, the challenge in SSA lies in the financial instability of developing countries and rural areas, where technology devices and internet access are costly. The financial constraint is worsened by the limited state funding for ICT resources in schools [10, 11]. These studies also investigate the impact of low teacher confidence in ICT use, a factor compounded by inadequate school infrastructure such as electricity and internet connectivity. There is a need for teacher training in digital skills and better-equipped schools, as these factors directly influence teachers' willingness to incorporate ICT into their teaching practices.

Furthermore, [10] highlights a significant gap in technology access, noting that only 16.1% of inhabitants in certain regions utilize fixed broadband subscriptions. This is exacerbated by high Internet Service Provider (ISP) charges, disproportionately affecting those in economically unstable countries. Aruleba and Jere [11] further report that in rural areas, where internet infrastructure is often insufficient, students rely on ICT services provided at schools. This disparity is compounded by the private sector's reluctance to invest in rural ICT projects, due to perceived lower chances of success. Moreover, funding from private companies, Non-profit Organizations (NPOs), and governments for ICT in developing countries and rural schools remains limited. This financial constraint hinders schools' ability to purchase necessary technology devices, which are often prohibitively expensive.

As [12] observes, limited state funding rarely includes specific allocations for ICT resources, leaving schools unable to afford essential technology. Stable internet access and effective communication are key to bridging the gap between teachers and students in ICT adoption. Without reliable connectivity, the potential benefits of digital learning and collaboration are significantly diminished. Shah et al. [13] argue for increased government investment to support and initiate new programs that can facilitate the use of ICT in teaching and learning. Such initiatives could provide teachers and students with the necessary resources and time to

effectively integrate ICT into educational settings, thereby boosting their confidence in using these technologies. Government involvement is crucial in overcoming these barriers. For example, the South African Electronic Communications Act of 2005 aims to ensure widespread ICT accessibility, yet its implementation has been lacking, particularly in disadvantaged areas. This lack of support leads to communication barriers and hinders the effective use of ICT in education.

The reluctance to use ICT is often rooted in low self-confidence among teachers, as identified by Haji et al. [6]. This lack of confidence is linked to the inadequate provision of ICT equipment in schools, where desktop computers are often limited to computer labs or administrative areas, and there is a lack of electrical connectivity. Providing teachers with personal laptops could help increase their comfort and confidence in using ICT. However, electricity supply remains a challenge in many SSA regions, necessitating the need for alternative solutions like spare batteries and routers for home internet access. Poor individuals often seek connectivity through alternative sources outside of school, such as in the private or public sectors, where mobile phones are more commonly used for internet access [10]. This scenario underscores the need for comprehensive strategies to improve access to ICT resources and build confidence in their use among educators and students in SSA regions.

This review underscores the urgent need for comprehensive strategies to overcome the challenges of ICT integration in SSA. With the right support and resources, ICT can be a powerful tool to transform education and bridge the digital divide in developing countries. The following section outlines the materials and methods employed during the study, focusing on the systematic approach to addressing these educational challenges in the context of SSA.

### **3 Materials and Methods**

This study adopts a systematic approach to aggregate, analyze, and synthesize findings from multiple studies, addressing specific research questions and producing comprehensive summaries or conclusions based on the combined evidence [14]. The dataset was collected from two databases Scopus and Web of Science (WOS) Results from a search term were exported to RIS format and finally populated to the Excel sheet. The search strategy focused on both Scopus and Web of Science academic databases, accessed on 04 May 2023, 01:35 AM. Reasons for opting for these academic databases are the quality of the content of ICT and science publication articles [11]. The following search terms were used for the literature search strategy, Scopus: (“ICT adopt\*” OR “adopt\* of ICT” OR “information communication technology adopt\*” OR “ICT us\*” OR “use

of ICT”) AND (“Rural school” OR “schools” OR “secondary school”) AND “factors”; Web of Science: (“ICT adopt\*” OR “adopt\* of ICT” OR “information communication technology adopt\*” OR “ICT us\*” OR “use of ICT”) AND (“Rural school” OR “schools” OR “secondary school”) AND “factors”.

The initial search yielded a total of 491 articles, comprising 381 from Scopus and 110 from WOS. This substantial collection of literature sources was then systematically exported to RIS EndNote and an Excel sheet. The purpose of this exportation was to facilitate a more thorough and organized screening process. Subsequently, a detailed analysis was conducted to filter out inapplicable literature. This step was crucial in refining the pool of articles to those most pertinent to our study’s objectives. The screening process involved a rigorous testing procedure to assess the relevance and validity of each article.

The inclusion criteria for the study are as follows: papers written in English, published between January 2017 and 2023, identifying ICT adoption, focused on rural areas and secondary schools, conducted in developing countries or regions, and containing both an abstract and conclusion, with the full text available (PDF or URL). The exclusion criteria include papers not written in English, published before 2017 or after 2023, not reporting ICT adoption, duplicates, full text not available, and book selections. For this study, a total of 38 factors have been identified from 84 research studies.

## 4 Principal Component Analysis

Principal Component Analysis (PCA) is a widely utilized multivariate statistical method that streamlines complex data sets by transforming them into principal components (PCs). These PCs are new, orthogonal variables that capture the most variance or information in the data, allowing for a more precise assessment of the underlying construct. By focusing on the most significant features, PCA facilitates data visualization and simplifies modelling without substantial loss of information [15]. PCA was conducted using the built-in functions of the stats package in R-Studio. As part of this process, data standardization, also known as scaling, plays a crucial role. Standardization ensures that each attribute contributes equally to the analysis by giving them all a mean of zero and a standard deviation of one. This is critical in PCA because variables measured at different scales do not contribute equally to the analysis.

To achieve standardization within R-Studio, the `scale()` function is employed. This function takes a numeric matrix as its input and performs scaling on its columns, effectively normalizing the data as per Eq. (1). The scaled data is then ready for PCA, where the extraction of PCs can reveal the most informative axes of data variation [16, 17].

$$Xil = \frac{Xil - Xn}{\sigma}$$

5 Results and Discussion

Figure 1 presents a PCA biplot illustrating the contribution (Ctr) of various factors (variables) to ICT adoption among rural students in developing countries. In PCA, variables that are both highly correlated and orthogonal signify a strong relationship. It can be observed that “over-digitalization,” “health challenges,” and “cognitive barriers” are orthogonally positioned with a Ctr of 7.5%. Furthermore, variables located on the right side of the biplot, or within Dimension 1 (Dim 1), exhibit a higher potential to influence ICT adoption. In this analysis, Dim 1 accounts for a larger variance (9%) compared to Dim 2 (7%). Consequently, variables situated from 0° to 180° are more contributory to the low adoption rate of ICT among students. In particular, variables at 135°, such as “over-digitalization,” “health challenges,” and “cognitive barriers,” are pivotal, for an in-depth analysis of the most and least contributory factors.

The biplot further indicates that variables at 180°–360° are negatively correlated with those at 0°–180°. Therefore, it can be deduced that variables positioned at 135° are significantly associated with lower ICT adoption rates in the studied context. These insights highlight the critical factors that need to be addressed to improve ICT uptake among rural students in developing countries.

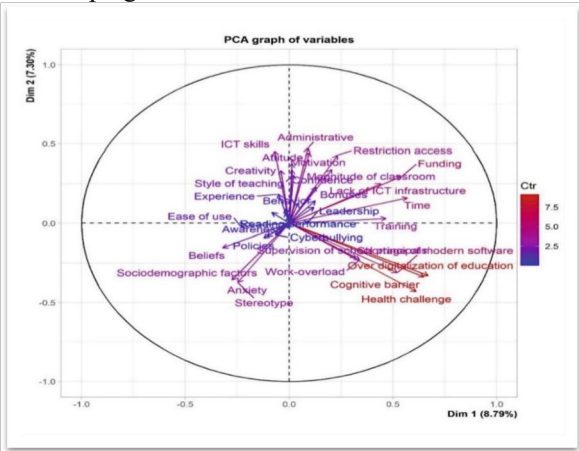


Fig. 1 PCA graph of contribution

Table 1 presents the first six principal component (PC) loadings, which serve as the correlations between each original variable and each corresponding PC. These PCs encapsulate the information content of 38 original variables through just 6 derived PCs. Each PC corresponds to an original variable, as outlined. PC1 is notably significant, explaining 79% of the variance observed in the original data set. This indicates that PC1 alone can represent a substantial portion of the information found in the original variables. Following PC1, PC2 explains an additional 30% of the variability in the data. This substantial contribution by the first two PCs is indicative of their importance in capturing the essence of the original dataset’s variability.

A commonly accepted heuristic for selecting PCs involves choosing the smallest number of PCs that cumulatively account for a significant portion of the variance, often surpassing a predefined threshold. Furthermore, for a variable to be considered strongly correlated with a PC, the correlation coefficient should exceed 3. This criterion helps in identifying the most relevant PCs that effectively summarize the original dataset’s variability.

**Table 1** The first six components’ loadings

| Principal components | Eigenvalue | Variance % | Cumulative variance |
|----------------------|------------|------------|---------------------|
| PC1                  | 3.34       | 8.79       | 8.79                |
| PC2                  | 2.78       | 7.30       | 16.10               |
| PC3                  | 2.29       | 6.02       | 22.12               |
| PC4                  | 2.11       | 5.55       | 27.67               |
| PC5                  | 2.04       | 5.37       | 33.04               |
| PC6                  | 1.95       | 5.13       | 38.17               |

**6 Discussion**

Many teachers express concerns that the educational process has become overly digitalized in the modern age. A study by Buda [18] highlighted that a significant proportion of teachers in 2006 shared this apprehension about the increasing digitalization of education. However, despite these concerns, digitalization remains one of the most effective approaches to teaching and learning in today’s world. Over-digitalization of technology in education often stems from the implementation of advanced technologies without adequate supporting infrastructure, such as reliable electricity, internet connectivity, or hardware availability, a common challenge in developing countries. Furthermore, introducing complex

technologies such as augmented reality [19] without addressing the digital literacy and skills gap within the population can discourage individuals from engaging with the technology. This can hinder the adoption of ICT among students, as they perceive it as overly difficult to learn and use effectively.

A cognitive barrier refers to factors that influence students' ability to effectively apply knowledge taught by teachers with the support of available technologies such as interactive whiteboards (IWBs), Wi-Fi networks, projectors, appropriate software, printers, and other peripheral devices. While these technologies enhance engagement, they can make it challenging for students to retain what is taught, as the enjoyment of using technology may distract them from learning. Additionally, health challenges such as depression and mental-emotional health issues have been shown to negatively impact ICT usage in non-developing countries [20]. To mitigate these adverse effects, the Department of Basic Education (DBED) should establish outreach programs in schools to educate students on the risks of overusing technology. Previous studies have highlighted how integrating IT devices in schools can affect students' health in various ways, underscoring the need for balanced and mindful use.

Time should be allocated for teacher collaboration, as noted by Gil-Flores et al. [21]. Time constraints can be a significant challenge when using digital technologies. Buda [18] conducted a study investigating "stumbling blocks and barriers to the use of ICT in schools," which revealed that the lack of ICT equipment in classrooms often causes delays of approximately 10–15 min for setup. In many schools, teachers share projectors and computers, and exchanging these devices between classes further exacerbates time consumption. In some cases, teachers carry projectors and computers from one class to another, which is neither efficient nor conducive to the teaching and learning environment. Both teachers and students generally prefer using their own devices, as it enhances the overall learning experience.

To address these challenges, schools should consider increasing the number of hours allocated to ICT subjects or modules during the planning and drafting of timetables rather than reducing them. This adjustment would provide teachers and students additional time to exchange devices, organize themselves, and prepare for upcoming classes. A study by Al-Mamary [22] highlighted that, despite the critical role of ICT in education, teachers often have insufficient time to integrate technology effectively into their lessons. Proper time management and planning can help create supplementary time for using technologies in teaching and learning processes.

Additionally, the timetable planning process should prioritize strategies to minimize time-consuming activities during and after classes. Schools should also invest in expanding ICT infrastructure, particularly in rural areas, to reduce delays and improve the efficiency of teaching and learning.

Providing sufficient resources and addressing time-related barriers are crucial steps toward enhancing the integration of ICT in education.

Funding is a critical factor in the growth of ICT in developing countries, yet it remains a significant challenge, particularly for rural schools, as investors often show little interest in funding projects in these areas. Affordability is a key barrier to ICT growth, as the high cost of technology disproportionately affects people in developing countries. To address this, students in rural schools must be provided with affordable or subsidized ICT technologies to ensure equitable access to ICT services. This lack of investment in rural projects further exacerbates the digital divide.

A study by Gil-Flores et al. [21] highlights the urgent need for increased investment in ICT infrastructure. Specifically, the Department of Basic Education (DBEd) should enhance funding for teacher training, the development of ICT projects, and the provision of appropriate software, such as educational programs. Such measures would foster a positive attitude among teachers and students toward adopting ICT in the classroom, promoting the integration of blended learning and eLearning. Notably, while some teachers remain sceptical about the value of technology, believing instead in traditional twenty-first-century teaching methods, investing in rural schools could bridge the educational gap between developing and developed countries and stimulate economic growth in Sub-Saharan Africa.

To achieve this, a collaborative effort is required from governments, private investors, and nonprofit organizations to provide high-quality and affordable technologies that align with the needs of modern education. Additionally, all regions in Sub-Saharan Africa must work collectively to secure funding, particularly in the Northern and Western regions, fostering stronger relationships between SSA investors and European countries. This unified approach could drive significant progress in education equality and economic development. Shortage of modern software and appropriate software for teaching and learning processes are the influential effects of the use of ICT in the classroom. These are factors that help the teaching and learning process to run smoothly without any further disruption barrier. The dissemination of modern software should be prioritized in schools to encourage students to integrate, use and adopt ICT in schools. An appropriate software, for example, a software program developed for text editing, graph creation, data organization, and calculations is essential for students as a useful tool and practice. Despite the importance of software, a study by Shala and Grajevci [23] reported a lack of educational software in Kosovo, this shortage of software contributes to the lack of ICT adoption and usability of available technologies for the teaching and learning process in schools. Additionally, some tertiary institutions have begun implementing mobile cloud virtual desktop infrastructure (VDI) [24] to supplement inadequate computer labs for students. However, students with

limited access to or proficiency in using ICT infrastructure may face significant challenges in completing their academic work.

To solve these major challenges there is a need for focusing to the over digitalization of technology, cognitive barriers, health challenges (issues), time, funding, and shortage of modern software toward the adoption of technology in rural schools and by focusing on these major factors the quality of education in rural schools can change to meet blended learning which includes the adoption of IWB, projectors, Wi-Fi, 4IR, 5G network, laptops, printers and other peripheral devices. The attendance of all these major factors, however, greatly improves the adoption of ICT efficiently. At the same time, policymakers need to bear in mind that, adopting ICT makes students work easily, but exploiting it in an unprofessional manner can prevent or hinder the process of teaching and learning. In addition, performing unprofessionalism is against ICT policy.

## 7 Conclusion

This study, encircling research from 2017 to 2023, analyzed 38 variables across 80 studies to understand the factors influencing the adoption of ICT in rural secondary schools in developing countries. The application of Principal Component Analysis (PCA) successfully reduced these variables to six primary factors that significantly impact the widespread adoption of ICT. These include over-digitalization of education, cognitive barriers, health challenges, time constraints, funding issues, and a shortage of modern software. These findings underscore the necessity for policymakers to deeply understand and address these factors using effective methodologies to improve ICT adoption in these regions.

The current state of lagging in ICT adoption in rural secondary schools in developing countries, particularly in Sub-Saharan Africa (SSA), compared to developed regions in the Western and Northern parts of the world, calls for urgent action. Addressing these challenges with speed and efficacy is crucial for empowering students to secure employment, establish businesses, reduce unemployment rates, and align with the goals of the Fourth Industrial Revolution (4IR), the Internet of Things (IoT), and blended learning. The insights garnered from this study provide a critical resource for combating low adoption and addressing key factors impeding the broad acceptance of ICT among rural secondary students in developing countries. These findings can also serve as an evidence base for investigating the negative effects of ICT in rural educational environments, offering a roadmap for future efforts to bridge the digital divide and enhance educational outcomes in these communities.

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