Integration of Smart Devices in Learning and Teaching of Science, Technology, Engineering and English Language: A Systematic Literature Review, 2010-2019

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Abstract

For several decades now, educators, policymakers, technologists, and researchers have been grappling with the challenge of enhancing student learning experiences. This challenge has been made complex by a multiplicity of factors, including: changes in the learning environment, emergence and increased use of intelligent devices such as smartphones and tablets, learners' attitudes and capabilities, employability crisis, and job market dynamics. Moreover, prior studies have asserted that although many researchers have reviewed mobile learning initiatives in different contexts, none has explored this subject in Africa. Although integration of smart devices in education, particularly in the teaching of English, mathematics, and science, has the potential to transform the learning experience, as well as achievement of learning outcomes, it remains unclear how integrating smart devices in education impact students' motivation, achievements, learning, and performance. This study reports a systematic review of the literature on smart device integration in education across various subjects. The review considered several attributes of each journal article publication, including the context of the studies done, only those articles in indexed journal databases, year and country of publication, devices used, research methods and theories used, sample size, learner level/category, and the study design adopted. The databases searched were EBSCOHost, Emerald, IEEE, INFORMS, JSTOR, SAGE, and Taylor and Francis. A total of 1382 studies published between 2010 and 2019 in seven indexed journal databases were analyzed, with 28% of the studies focusing on K-12 or primary education and 9% on secondary schools. The main findings from this review provide the current research on the state of smart device integration in education. The study established that smartphones and tablets/iPads contribute fifty percent (50%) of the devices integrated into the learning and teaching of various subjects. Further, Asia and Africa are leading in smart device integration in education. However, the United States of America is leading in studies published in journal databases. Additionally, the case study approach was the most common study design, while K-12/primary education contributed twenty-eight (28%) of all participants in the studies reviewed. This paper discusses the trends and the vision for the future. It focuses on how the integration of smart devices in education can potentially influence students' achievement of learning outcomes in STEM and English language. This review has laid the groundwork for researchers, educators, technology developers, and other stakeholders involved in the improvement of the outcomes of educational programs for learners. The findings offer new empirical evidence-based insights on the influence of smart

devices on improving learning outcomes and the learning experience by integrating the devices into educational teaching and learning.

Keywords: Smart devices, Education, STEM, Mobile learning, Science, Africa.

1. Introduction

Development in information and communication technologies (ICT) has dramatically affected education systems worldwide. Scholars, educators, and policymakers have been grappling with successfully integrating ICT, specifically smart devices, into all processes and activities in education (Göksu & Yurtkan, 2016). This is due to the capability of ICT to provide dynamic and proactive teaching and learning environment and improved learning outcomes. Unfortunately, prior studies have established several challenges in the integration agenda (Adedoja, Adelore, Egbokhare, & Oluleye, 2013). These challenges include unequal access to the internet and smart devices between countries, schools, and even homes. Moreover, the scholars have not approached the integration agenda with harmony in the theoretical approach and smart devices alignment to learning and teaching. In this paper, a smart device is an electronic gadget that connects to other devices or networks via different protocols such as Bluetooth, NFC, WiFi, 3G, 4G, 5G, and the internet. Additionally, it should be able to share and interact with its user as well as other smart devices (Silverio-Fernández, Renukappa, and Suresh, 2018).

2. The Problem

Previous studies have posited that large-scale studies evaluating the effectiveness of smart devices within higher learning institutions in Africa are inadequate (Kaliisa & Picard, 2017). The authors continue to argue that existing studies lacked a theoretical foundation. These two inadequacies established by Kaliisa and Picard (2017), reveal insufficient penetration of smart device technologies and associated pedagogies within higher learning institutions in Africa. This paper, therefore, responds to the call by Kaliisa and Picard (2017) to address this gap and strengthen research in this emerging area of study. Moreover, some contemporary researchers like the International Telecommunication Union (ITU) posit that the amalgamation of smart devices, cloud-based services, and intelligent technologies and networks offer a powerful means of enhancing and extending the learning experience (ITU, 2018). This proposition was echoed in the Innovation Africa (2018) meeting in their quest to implement ICT-based education projects. However, the problem of enhancing learning and teaching remains persistent in this digital era.

3. Research Questions

Researchers have used numerous methods to identify and select manuscripts in review studies (Akçayır & Akçayır, 2017). In this review, scientific articles were selected based on the

educational uses of smart devices—smartphones and tablets—published in select journals indexed as EBSCOHost, Emerald, IEEE, INFORMS, JSTOR, SAGE, and Taylor and Francis. This review collates and compares studies published between 2010 and 2019 on the application of smart devices for STEM education and English Language in the African context. The study aims to answer the following questions:

RQ1: What is the distribution over time of the studies published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

RQ2: What smart devices are published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

RQ3: What learner types (types of participants) are commonly selected for the research studies published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

RQ4: What research approaches are commonly selected for the research studies published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

4. Relevant Literature

Studies have shown that as the proliferation of mobile devices in higher education increases and the relative cost decreases, bringing your own device is seen as commonplace as bringing your pen, paper, or calculator to university (Bruno, 2019). However, despite this movement, the different ways students and faculty use smart devices have made it difficult to establish a Bring Your Own Device (BYOD) policy. Even with these difficulties, the thriving web has been an emerging force in fanning the use and application of smart devices in education. Indeed, previous scholars have established this point of view by asserting that the advent of smart devices ensures that this thriving web, and the teaching and learning it supports, is also unbounded (Molina-Carmona & Villagrá-Arnedo, 2018).

For instance, prior researchers acknowledge that globalization and the rapid development of ICT are transforming society. Subsequently, STEM is necessary to meet the demands of 21st-century workplaces (Hooker, 2017; Ismail, 2018). Thus, smart devices help students to study at any time and anywhere. They also remove distance limitations (Göksu, Karanfiller, & Yurtkan, 2016). Table 1 highlights the characteristics of SMART education.

5. Methodology

5.1 Planning the review

The review process began by refining the research objectives into research questions. The researcher also identified the search strategy, search strings, inclusion and exclusion criteria, and

the quality assessment criteria to apply to the extracted studies. A detailed presentation of this process is articulated below.

Table 1. Characteristics of SMART Education

Initial	Feature	Details
S (Self-directed)	Knowledge manufacturer	Change in the role of the student from the consumer to the provider; the role of the instructor from the knowledge messenger to the educational mentor
	Intelligent	A self-conducted learning system with an online achievement evaluation and prescription
M (Motivated)	Experience-centered	Emphasize the experience-centered learning method in the standardized textbook-based education system
	Problem-solving	Aim for creative problem-solving and process-based individualized evaluation
A (Adaptive)	Flexibility	Enforced flexibility of the education system and personalized learning experience, based on preferences or future careers
	Individualization	Role of school changes from delivering mass knowledge to providing individualized learning with regard to the level and the aptitude of the student
R (Resource-free)	Open market	Based on the cloud educational service; various contents developed by members of the public or private individuals are applied to the education system
	Social networking	Expansion of collaborative learning using domestic and overseas learning resources, collective intelligence and social learning
T (Technology embedded)	Open education	An open environment that offers desired learning experience regardless of time and place and also guarantees maximum learning options with various education systems

Source (Park, Choi, and Lee 2013).

5.1.1 Search strategy

Previous studies have established a guideline for conducting systematic review research (Pellas, Fotaris, Kazanidis, & Wells, 2018). This review's search space included seven electronic databases, as shown in Table 2. So as to obtain a comprehensive view when answering the research questions, it was essential to run the search on specialized databases from the computer science or engineering discipline and the education discipline, hence the selection of the seven databases. The selected publication period was from January 2010 to November 2019. Consequently, the initially retrieved studies from the electronic databases were analyzed. The inclusion and exclusion criteria, explained in Section 5.1.2, were applied to all the studies kept after the initial analysis to filter the remaining papers.

5.1.2 Search criteria

The search criteria used for this review consist of three parts defined as follows:

- Keyword1 is a string made up of keywords related to smart devices such as "smart devices" or "smartphone" or "tablet" or "laptop" or "PC".
- Keyword2 is a string made up of keywords related to education such as "education" or "teaching" or "learning".
- Keyword3 is a string made up of keywords related to subjects such as "mathematics" or "STEM" or "science" or "engineering" or "technology" or "English language"

Table 2. Search Sources

Electronic databases	Searched items	Search applied on	Paper Language	Publication period
1. EBSCO Host 2. Emerald 3. IEEE 4. INFORMS 5. JSTOR 6. SAGE 7. Taylor and Francis	Journal, workshop, and conference papers	Full text—to avoid missing any of the papers that did not include the search keywords in titles or abstracts but were relevant to the review object	English	From 1st January, 2010 to 30th November, 2019

The Boolean expression search criteria used were "Keyword1, Keyword2, and Keyword3". An example of a search done in the electronic databases was "smart devices" and "education" and "English language" for each keyword, respectively. The search string in each of the four databases manually was based on the search functionality offered by that database.

5.1.3 Inclusion and exclusion criteria

To determine whether a study should be included, the researcher used the following inclusion and exclusion criteria: **Inclusion criteria:** (a) the study is a peer-reviewed publication; (b) the study is in English; (c) it is relevant to the search terms defined above; (d) it is an empirical research paper, an experience report, or workshop paper; and (e) the study is published between 1st January 2010 and 30th November 2019. **Exclusion criteria:** (a) studies that do not focus explicitly on smart devices and STEM or English language; (b) studies that do not address the education domain; (c) studies that do not meet the inclusion criteria; and (d) all other items that are typically assumed to be non-reviewed including prefaces, tutorials, anecdote papers, books, keynotes, viewpoints, editorial comments, and presentation slides.

5.2. The data coding and analysis processes

All of the articles were coded and analyzed. The four research questions (RQ1, RQ2, RQ3, and RQ4) address the publication year, smart device type used and integrated into education, learner type that participated in the study, and research design type. The year is the date of publication in the journal, as indicated in the article. The smart devices integrated into education were divided into five categories: smartphones; smartwatches and others; tablets/iPad; laptop/desktop PC; and "not indicated/specified" (denoting the smart device type was not clearly specified, or the paper discussed the integration of smart devices in education but did not collect data from the use of a particular smart device). In some papers, more than one smart device type was discussed, such as smartphones together with tablets (Nincarean, Alia, Halim, & Rahman, 2013; Squire & Klopfer, 2007). In these kinds of studies, the device with the larger sample was the code applied for the smart device type, while the other smart devices were put in the "other devices" column.

Learner type was divided into ten sub-categories of participants: kindergarten; K-12 or primary pupils; secondary school students; undergraduates; graduates; teachers; special students; adults; college students; and "not indicated/specified" (denoting the learner type was not clearly specified, or the study discussed the integration of smart devices in education but did not collect data from any learner type). In some studies, more than one learner type was discussed, like university students alongside K-12 students (Squire & Klopfer, 2007). In these kinds of papers, the code applied for the learner type was on the more prominent or larger sample, while the other learner types were put in the "other learner types" column (Akçayır & Akçayır, 2017).

The research design type was divided into eight sub-categories of participants: literature review; cross-sectional survey, longitudinal survey; meta-analysis; descriptive; ethnography; experimental, and not indicated/specified (denoting the research design type was not clearly defined). In some studies, more than one design type was discussed (Squire & Klopfer, 2007). In these kinds of papers, the design that was used to generate the more prominent or larger sample was the design applied, while the other design types were put in the "other design types" column (Akçayır & Akçayır, 2017).

3. Findings

RQ1: What is the distribution over time of the studies published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

To address this study question, the researcher analyzed the distribution over time of the studies published in the indexed journals that examine the integration of smart devices in education in the learning and teaching of English and STEM subjects. Answers to the studies distribution on the following three aspects were sought:

a. Distribution over the years 2010-2019,
b. Distribution in selected indexed journal databases, and

c. Distribution over countries of research.

1.1 Distribution Over the Years

The analysis of the distribution of the articles on the integration of smart devices in education across ten years of publication revealed that starting in 2010, the number of studies gradually increased over time. Table 3 summarizes the inclusion and exclusion criteria.

Table 3. Inclusion and Esxclusion Criteria

Inclusion criteria	Exclusion criteria
a) Must include smart devices, tablets/iPad, smartphones, integration education, and all or any of English language, STEM, mathematics and science as a primary component.	a) Editorials, magazines, newspapers and other non-journal sources are excluded.
b) The article must be about the use of smart devices for educational purposes.	b) Articles that mention the term smart devices, tablets and/or iPad, smartphone, but are actually about the devices themselves or other topics.

Spector (2016) provides an overview of smart technologies in education and their potential for the future. He argues that although much is happening in the broad area of applying smart devices to learning and instruction, the future appears quite promising. Unfortunately, large-scale, systemic improvements have yet to emerge (Spector, 2016). The number of smart devices integrated into the English language, mathematics, and science learning and teaching has progressively increased since 2011, indicating that more research interest has been focused on it, as shown in Figure 1. One of the likely reasons for this increase is that the use of smart devices in education has become widespread. After 2010, advances in mobile technologies, especially smartphones and tablets, and an increase in the number of mobile device owners were apparent (Spector, 2016).

This intense integration of smart devices into education research over the last ten years suggests that a similar level of interest will continue in 2020 and beyond. Particularly in developing countries, where affordable smart devices and internet use are increasing rapidly. Therefore, it seems likely that the use of smart devices in educational settings will increase and thus, more research will be devoted to this subject (Spector, 2016).

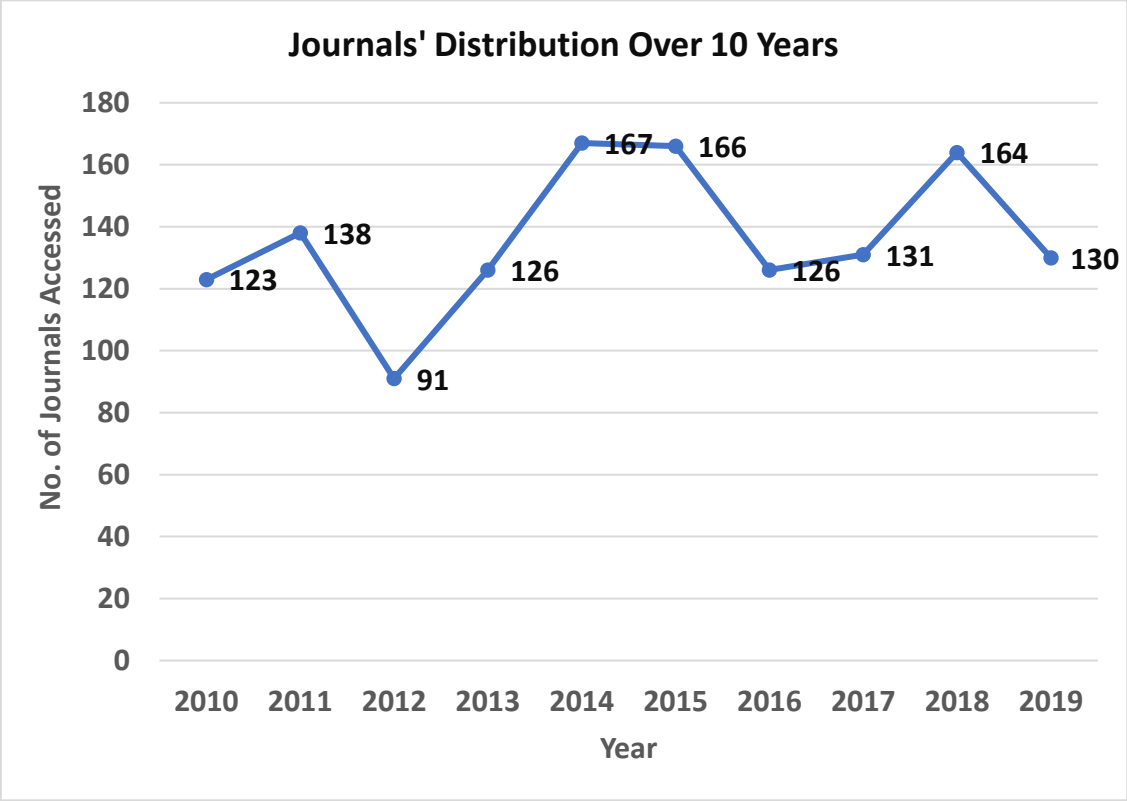


Figure 1: Number of Articles Published by Year

1.2 Distribution in Selected Indexed Journal Databases

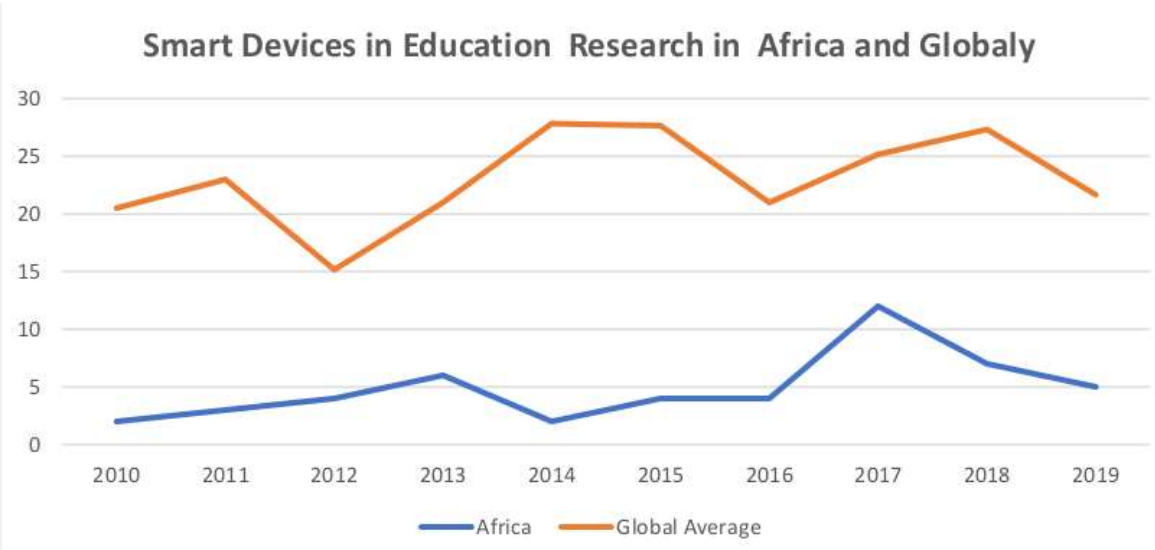


Figure 2: Smart Devices in Education Research in Africa and Globally

Figure 2 shows that Africa, on average, lags behind when compared to the other six continents when it comes to indexed journals for smart devices integration into education across the ten years covered by this study. Out of the 1382 journals studied, only 49 (3.5%) papers covered research done in Africa.

Seven indexed journal databases were used to review the 1382 studies. Figure 3 shows the number of articles that focused on the integration of smart devices in the learning and teaching of English language and STEM subjects. As shown in Figure 3, almost half of the articles were from the Emerald database. The seven indexed databases were conveniently selected.

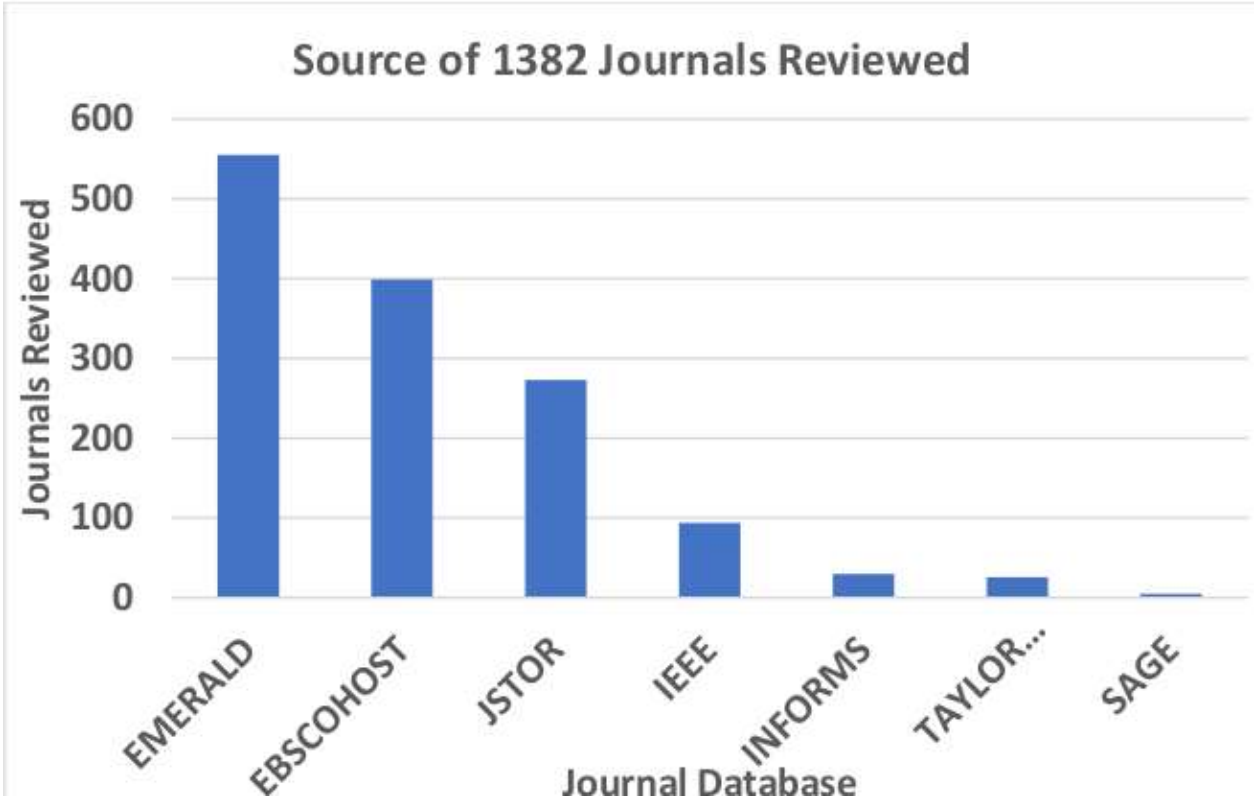


Figure 3: Sources of Reviewed Journals

1.3 Distribution Over Countries of Research

Figure 4 shows the top 20 out of the 81 countries reviewed in the published articles that focused on the integration of smart devices in the learning and teaching of English language and STEM subjects. Out of the top 20 countries reviewed, South Africa is the only African country at number 14 in this category with fifteen (15) studies.

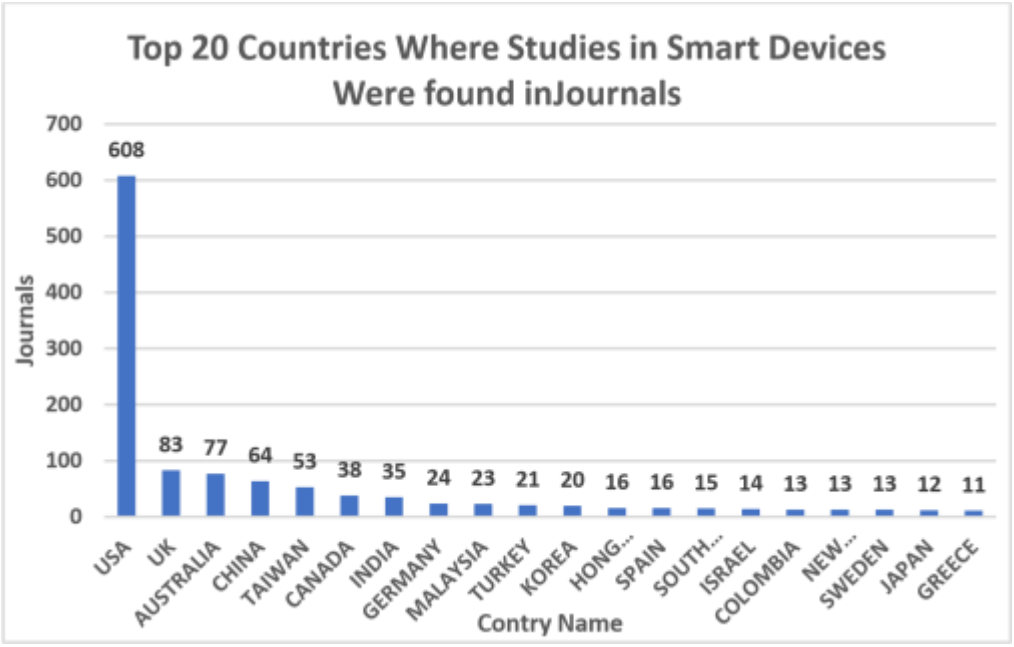


Figure 4: Top 20 Countries with Reviewed Studies

RQ2: What smart devices integrated into education are published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM?

Digital electronic resources can be accessed with different smart devices, including tablets, smartphones, wearable watches, laptops, or personal computers (PCs). Different smart devices have different characteristics depending on cost, accessibility, and usability in educational settings (Akçayır & Akçayır, 2017).

2.1 Smart Devices Dominant in Education

The review identified the most preferred or dominant smart device integrated into education for English and STEM learning and teaching as smartphones at 26%, as shown in Figure 5.

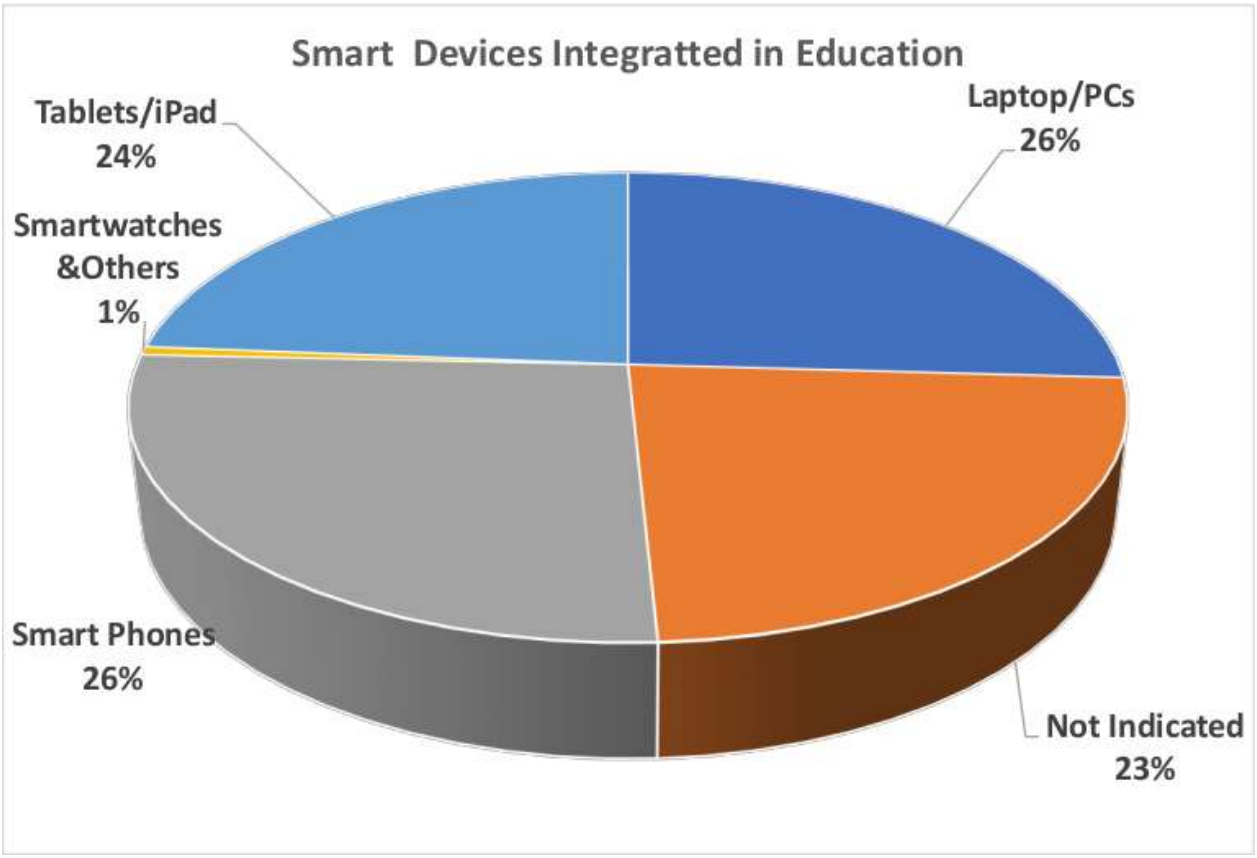


Figure 5. Smart Devices Used in Education

2.2 Use of Smart Devices in Education

The studies on integration into the learning and teaching of English language and STEM subjects reveal that in Africa, the use of smartphones in education is higher than in any other continent except in Asia, as shown in Figure 6.

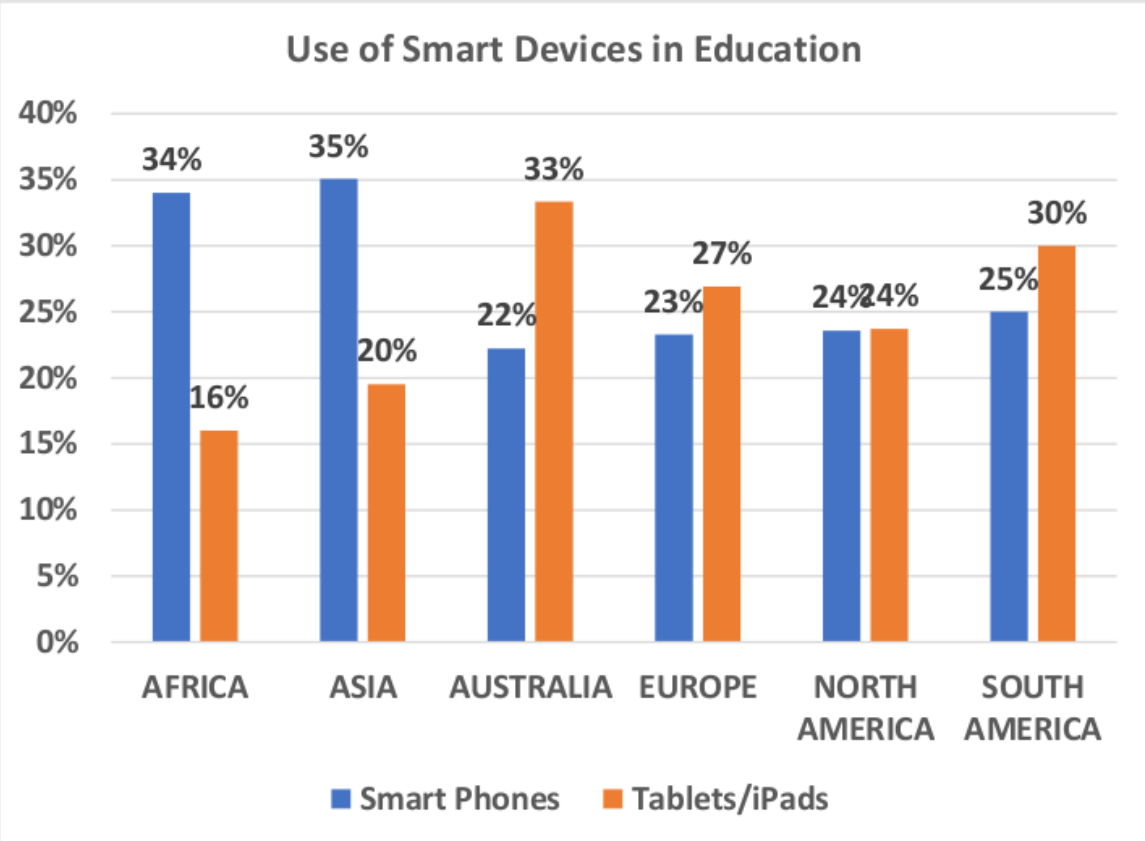


Figure 6: Use of SmartPhone and Tablets/iPads in various Continents

RQ3: What learner types (types of participants) are commonly selected for the research studies published in the indexed journals that examine the integration of smart devices in education in the learning and teaching of English and STEM?

Figure 7 shows that in nearly thirty percent of the articles (28%), K-12 or primary students were the commonly selected learner type for research studies in this area. University students, at 21 percent, were the second most commonly preferred learner type. According to Akçayır and Akçayır (2017), this trend is justified since elementary students and early adolescents are at the concrete operational stage. According to Piaget's stages of cognitive development, they must see, hear, or in some other way, use their senses to learn (Martin & Loomis, 2013). Thus, the strong interaction features typical of smart devices play an important role in learning for pupils at this stage. This may explain why primary school pupils are the most preferred sample groups. Another potential explanation is that many children spend a lot of time playing digital games. Therefore, researchers may find educational games and simulations highly suitable for engaging young students in learning (Lee, 2012).

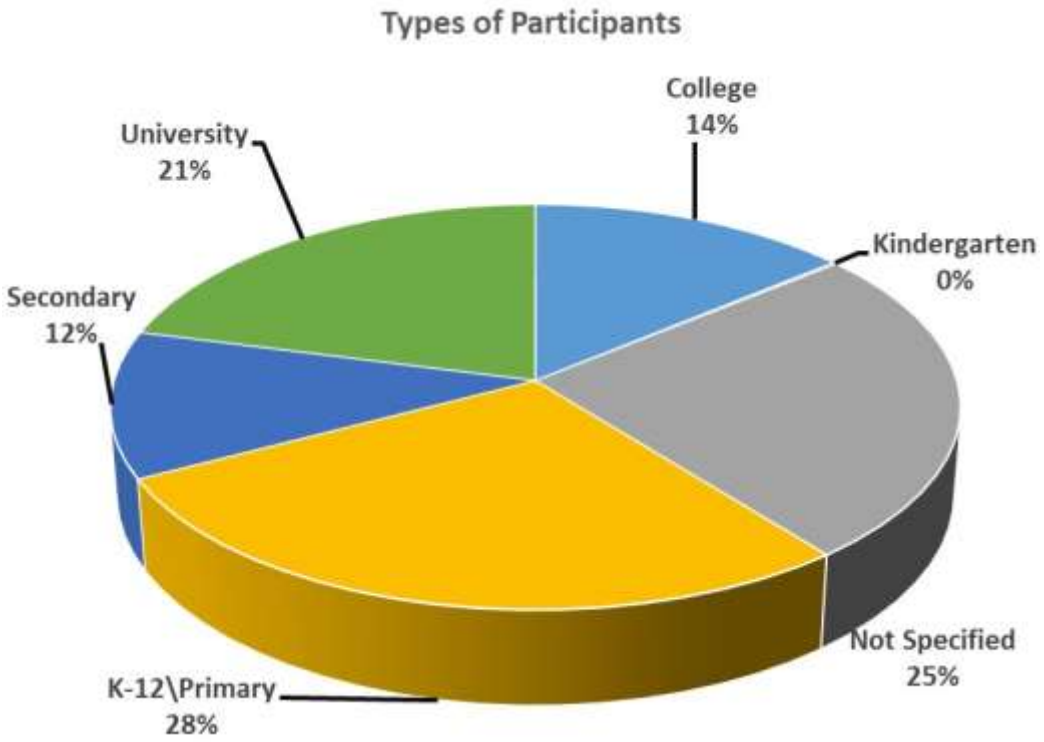


Figure 7: Types of Participants

Only two researchers utilized subjects from the kindergarten level in this study, which is almost 0% of the reviewed articles. Fourteen percent (14%) of the research focused on college learners. Smart devices were found to be a potentially effective tool and easy to use. The review concurred with Akçayır and Akçayır's (2017) findings, which revealed that there exists a notable gap in studies on the use of smart devices in education that focuses on students with special needs. This study similarly agrees with prior studies that posit that few technologies designed for students with special needs exist (Wu, Lee, Chang, & Liang, 2013).

RQ4: What research approaches are commonly selected for the research studies published in the indexed journals that examine the integration of smart devices in education in the learning and teaching of English and STEM?

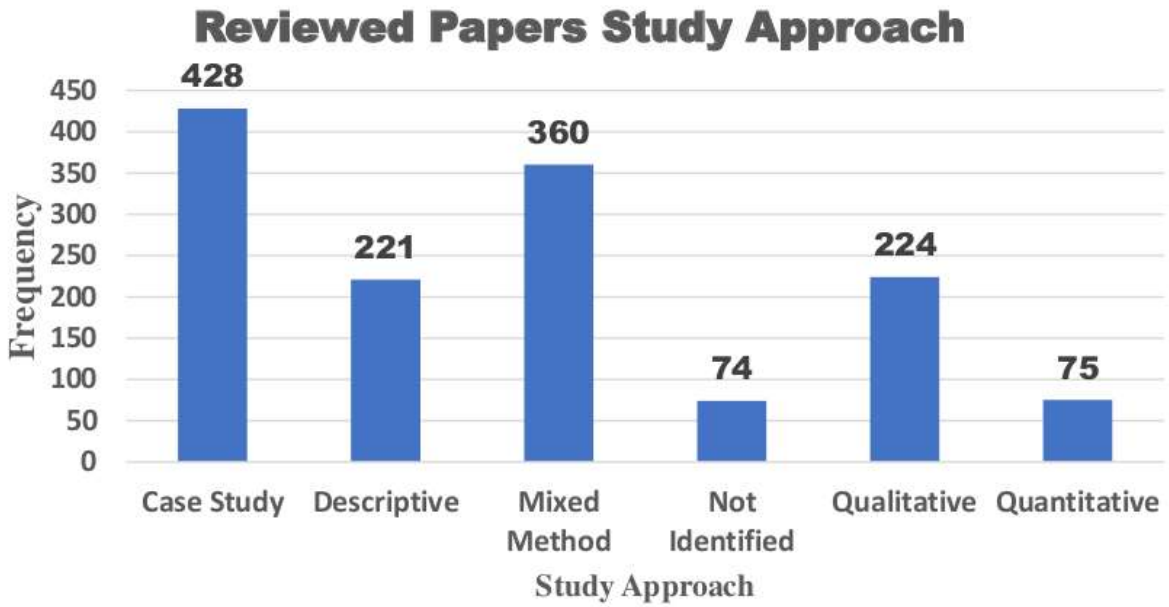
4.1 Research Approaches

The reviewed papers established the dominance of five research approaches. Four hundred and twenty-eight studies employed case study research, which involves an in-depth inquiry into a subject or phenomenon within its real-life setting (Saunders, Lewis, & Thornhill, 2016). According to Saunders, Lewis, and Thornhill (2016), a 'case' in case study research can refer to an individual (e.g. an administrator), a group (e.g. employees), an organization (e.g. a company), an association (e.g. a joint venture), a change process (e.g. restructuring a firm), an event (e.g. an annual athletics championship) among other types of case subjects. The cases included universities, colleges,

secondary, primary schools, and kindergartens in the papers that were studied, as shown in Figure 7 above. On the other hand, 360 papers used a mixed-method research design, which encompasses quantitative and qualitative research within the same study to understand a research problem (Saunders, Lewis, & Thornhill, 2016; Creswell & Creswell, 2018).

The next most popular approach was qualitative research, which emphasizes using words rather than figures in collecting and analyzing data (Berg & Lune, 2017). This approach was used in 224 studies. This was followed by 221 studies that employed descriptive research. Saunders, Lewis, and Thornhill (2016) posit that descriptive research aims to gain an accurate profile of events, entities, objects, persons, or situations. They further argue that descriptive research questions are likely to begin with, or include, either "who", "what", "where", "when" or "how". In the papers that were reviewed, the entities profiled included students, teachers, smart devices, parents, schools, colleges or universities, as illustrated in Figures 4 to 7 above.

Last, although different researchers and educators give different definitions to "quantitative research", their definitions largely include the fact that quantitative research is the numerical representation and manipulation of observations to describe and explain the phenomena that those observations reflect. One definition asserts that quantitative research evaluates objective theories by testing the relationship between variables. In turn, these variables are measured naturally on instruments to analyze numerical data using statistical procedures. Usually, the final written report, whether a thesis or journal article, has an established structure that is introduction, literature, theory, methods, results, and discussion (Creswell, 2014). This category had 75 articles.



4.2 Data Collection Methods

Among the papers that were reviewed, the data collection methods included focus groups (38.0%), questionnaires (29.0%), observation (12.1%), interviews (10.9%), and literature review (2.7%). A

number of papers did not have clear data collection methods and hence were put in the category of 'not indicated' (7.2%). A questionnaire may be defined as a document comprising questions and other items designed to solicit information appropriate for analysis (Babbie,1990). Questionnaires are used in survey research, experiments, and other modes of observation. Certainly, people ask different questions in their daily lives to answer their queries. Such people may include journalists, market researchers, observers, and interested persons in different events and issues in life, society, and organizations. They ask a set of questions to other people, including employees, students, citizens, parents, or even users of technology. They then form an opinion or conclusion according to the answers they receive. The use of the questionnaire or a set of questions is a similar process in research. The research questions are firmly constructed to receive answers related to the chosen variables for analysis. Surveys are designed to produce statistics about a target population. The statistics aid the researcher in forming an opinion or conclusion on the population represented by the sample according to the answers that they receive. Two of the key goals of the survey methodology are to curtail errors in data collected by surveys and to quantify the error that necessarily is part of any survey (Fowler, 2014).

The research interview is a general term for several types of interviews. This is important since the nature of any interview should be consistent with your research question(s) and objectives, the purpose of your research, and the research strategy that you have adopted. Prior studies have posited that there are a number of different types of interviews depending on the research purpose. These include semi-structured, in-depth, and group interviews, where the interviewer generally gets completed responses (Saunders et al., 2016). Observation is a tool used to systematically observe the behavior of study participants following a defined schedule of categories (Bryman, 2012). A literature review or content analysis involves the analysis of documents and texts following a predetermined category (Tracy, 2020). The results and percentages of data collection methods used in the reviewed papers are shown in Table 4.

Table 4. Distribution of Data Collection Methods

Method	Frequency	Percent
Focus Groups	525	38.0%
Questionnaires	401	29.0%
Observation	167	12.1%
Interviews	151	10.9%
Not Indicated	100	7.2%
Literature Review	38	2.7%
Total	1382	100.0%

4.3 Theoretical Frameworks Used Smart Devices Integration in Education

The study investigated the theoretical frameworks commonly used in the integration of smart devices in the teaching and learning of STEM subjects, the English language, and the pedagogy of these subjects. From the review, 66.4% of the studies were based on a framework, while 33.6% did not have any clear theoretical framework. Most of the frameworks used relate directly to smart device adoption and acceptance integration in education, while others are based on learning theories, such as social learning and constructivism. The frameworks include a theory of mobile learning, eLearning theory, educational science theory, experiential learning theory, game-based learning theory, institutional theory, language acquisition theory, social cognitive theory, achievement goal theory, social constructivism pedagogy theory, the mathematical theory of communication, transformative learning theory, visualization theory, and Davis's technology acceptance model. Other frameworks include Reeves and Oliver's nine characteristics of authentic learning, Roger's diffusion of innovations (2003), social learning constructivist theory, the unified theory of acceptance and use of technology, the framework for the rational constructivism theories, and learning theories.

4. DISCUSSION

This section summarizes and discusses the main findings in line with previous studies, the identified weaknesses from the reviewed studies, and recommendations for policy and future research. The findings and discussion are related to smart device integration into STEM subjects and the English language. One of the key research questions addressed by this study was to establish the countries of research within the context of smart device integration in education. This feature was important to compare the research output from Africa and the rest of the world and within African countries. Within Africa, our study results agree with those of Kaliisa and Picard (2017) that South Africa is leading on the African continent in studies in the area of smart device integration in education. Further, we observe that studies conducted in Africa on integrating smart devices in education are scanty.

Another factor under review was how smart devices were integrated in learning and teaching English and STEM subjects. The study results show that tablets and smartphones combined are the most used devices in education, contributing 50% of all devices studied. These results are consistent with Akçayır & Akçayır's (2017) findings that mobile devices combined contributed 60%. This percentage is expected to be higher in the African context, where many of the learners may never have an opportunity to use a computer.

The learner types or types of participants that were commonly selected for the research studies published in the indexed journals were established using a select journal that was accessible to the researcher. Undergraduates and K-12 or primary students contributed 45% of all participants in the selected journals. The finding agrees with those of Akçayır and Akçayır (2017), who found that participants from higher education and K-12 contributed 80%. The difference is likely from the different journal databases used in the two studies.

The research design type, data collection methods, and theoretical framework commonly selected for the research studies published in the indexed journals that examine the integration of smart devices in the learning and teaching of English and STEM were considered. Emphasis on these characteristics was imperative to comprehend how study findings and conclusions are constructed (Kaliisa & Picard, 2017). The review in this paper established that case studies had formed a large percentage of studies (428), followed by mixed-method studies (360), qualitative studies (224), and finally, descriptive studies (221). These findings are consistent with Kaliisa and Picard (2017), who, in their Systematic Review on Mobile Learning in Higher Education: The African Perspective, reported mixed methods and case studies as the most used approaches in the reviewed studies. The use of case study methods in smart device integration in education is perhaps due to the desire by researchers to pursue this phenomenon from an educational environment like a primary school, secondary school, college, or university. Similarly, they seek to understand the issues in an educational segment, including kindergartens, K-12, high schools, and tertiary institutions like universities. Additionally, the large number of case studies might be defensible because smart device integration in education is an emerging field of research. Consequently, this perception's limitations and context are not yet apparent. Thus, case studies focusing on a phenomenon within its normal context are preferred (Kaliisa & Picard, 2017).

Further, five methods of data collection were reported in the reviewed studies focus groups (38.0%), questionnaires (29.0%), observation (12.1%), interviews (10.9%), and not indicated (7.2%), literature review (2.7%). The large number of studies that use focus groups resulted in many facultative studies. The use of focus groups can be explained as emanating from the desire to explore the perceptions, experiences, benefits, and challenges in integrating smart devices in learning and teaching. This being a relatively new area of research, many issues are yet to be established as the norm. Questionnaires are possibly high due to their ability to gather data from a large population compared to other methods like a case study, content analysis, and observation, given the large population that characterized most of the reviewed studies (Bryman, 2012). For instance, the study by Ebbeck, Yim, Chan, and Goh (2016) had 1058 participants; Macharia and Pelser (2014) had 1800; Park and Jo (2017) had 7940; Pearson (2014) had 2252; and Wilson et al. (2015) had 1507. Therefore, based on these figures, the popularity of questionnaires in the reviewed studies is admissible. However, the absence of tests as a data collection instrument across many of the studied articles can be considered a methodological weakness. This assertion holds because tests are among the most useful educational research tools. For instance, the studies by Klimova (2019), Ogunmakin (2018), and Zawaideh (2017) intended to measure student achievement by use of mobile learning did not utilize achievement tests in both methodology and findings, which would have been used to confirm valid and reliable results.

The study investigated the theoretical frameworks commonly used in integrating smart devices in the teaching and learning of STEM subjects, the English language, and the pedagogy of these subjects. From the reviews, 66.4% of the studies were based on a framework, while 33.6% did not have any clear theoretical framework. Most of the frameworks used relate directly to smart device

adoption and acceptance integration into education, while others are based on learning theories, including social learning and constructivism. The frameworks include: a theory of mobile learning (Sharples, Taylor, & Vavoula, 2005); eLearning theory (Mödritscher, 2006); educational science theory (Norris & Kvernbekk, 1997); experiential learning theory (Kolb, Boyatzis, & Mainemelis, 2014); game-based learning theory (Malhotra, 2016); institutional theory (Lammers & Garcia, 2017); language acquisition theory (Goldin-Meadow, 2008); social cognitive theory (Compeau, Higgins, & Huff, 1999); achievement goal theory (Christenson, Wylie, & Reschly, 2012); social constructivism pedagogy theory (Pear & Crone-Todd, 2002); the mathematical theory of communication (Anantharam, 1996); transformative learning theory (Kitchenham, 2008); visualization theory (Padilla, 2009); technology acceptance (TAM) (Davis, 1989); authentic learning (Oliver, Herrington, Herrington, & Reeves, 2007); diffusion of innovations theory (Rogers, 2003); social learning constructivist theory (John, 2013); unified theory of acceptance and use of technology (Venkatesh & Zhang, 2010); a framework for the rational analysis of mobile education (FRAME) (Koole & Ally, 2006). The cognitive theories were the most used (represented in 12 studies), followed by constructivism theories and learning theories. However, 33.6% of the studies whose analyses were not based on any framework had questionable findings and conclusions (Kaliisa & Picard, 2017). This is because previous researchers like Reeves, Albert, Kuper, and Hodges (2013) have asserted that a study interpretation and understanding of the social world can lack meaning without theory.

The reviewed studies provide sufficient evidence that the integration of smart devices into English and STEM education faces a substantial number of challenges. These issues include poor access to smart devices, relevant digital content, internet access problems, lack of smart devices, learning pedagogical skills among teachers, and sometimes poor attitude among students and teachers. Others are the absence of policies to guide the implementation of smart education, as well as the fact that different smart devices have different functionalities (Adedoja, Adelore, Egbokhare, & Oluleye, 2013). The challenges mentioned in this study are in agreement with those raised by Johnson et al. (2016) and Adams et al. (2017) on the challenges facing the integration of smart devices in learning and teaching. They recognized connectivity, which is limited in many parts due to the cost of data, poor internet connection speed, poor quality or lack of smart devices with inadequate functionalities, and small screens as challenges facing the integration of smart devices in education (Koneru, 2019).

The above discourse and findings have far-reaching meaning for educators, researchers, and policymakers. First, the use of smart device integration is increasing at all levels of education. Thus, educators at all levels of education need to plan, implement, and manage a future where smartphones and other devices are integrated into all the processes and activities in education. On the other hand, governments and policy and curriculum development agencies should take cognizance of a future where smart device integration in learning and other educational processes will be apparent. Finally, the researchers are called to conduct more participatory action research on smart device integration in learning and teaching to provide evidence-based advice to education practitioners and policymakers.

5. Limitations and Identified Gaps

Several gaps were identified in studies focusing on smart devices in STEM education and English language teaching and learning. First, a substantial number of studies (36.6%) did not base their research on any theoretical foundation, which places the findings and conclusions into doubt. This is because theory establishes the basis for comprehending complex problems, interpreting empirical data, avoiding the unorganized collection of details, as well as establishing a basis for illumination and analyzing the way study subjects respond or behave in the real-world context (Reeves, Albert, Kuper, & Hodges, 2013).

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6. Conclusion and Suggestions for Future Research

The number of studies on smart device integration in STEM education and English language learning and teaching is growing exponentially. However, there are still very few high-quality studies to establish data-based evidence for its effectiveness. Nonetheless, the study findings point to an increasing interest in the integration and use of smart devices in education.

With the falling costs and increasing spread of smart devices, the future of smart device integration in STEM education and English language learning and teaching is encouraging. For example, the analysis seems to suggest an increasing interest in smart device integration in STEM education and English language learning and teaching research globally. The large number of papers published between 2011 and 2019 agrees with the findings by Johnson et al. (2016) and Adams Becker et al. (2017), which established that there was a growing trend in smart education within developing countries. This is an inspiring development demonstrating a growing interest in researching smart education globally and, in particular, African higher education.

The discussion section of this paper has established several challenges that need attention. Smart devices integration in STEM education, English language learning, and teaching is to be fully integrated into education systems and institutions: teachers and students should be provided with technical support on the use of smart device technologies; smart device-based learning management systems should be designed in a manner well matched with a variety of smart devices; course developers should be provided with skill upgrade and technical skills where lacking; and internet access should be provided or enhanced in educational institutions, including in student transport, student dormitories and residences, libraries and classrooms (Kaliisa & Picard, 2017). These interventions will mitigate some challenges, including students' internet costs (Adedoja et al., 2013).

Finally, the study recommends future research to conduct longer and larger-scale studies investigating the impact of smart device integration in STEM education and English language learning and teaching. This is because the majority of the studies were executed within a short duration. Additionally, further research is recommended targeting particular continents or particular education sectors, for example, higher education or high schools.

Furthermore, given the limited theories of smart device integration into education, future research should use the existing mobile learning theory, theory of eLearning, and other associated educational technology frameworks to offer a lens through which research findings and results can be organized and interpreted. No doubt, then, if these matters are addressed, the impact of smart device integration in STEM education and English language learning and teaching can be correctly assessed. Further, the study results were used for several benefits, including informing policy for the use and integration of smart devices integration in STEM education and English language learning and teaching; designing appropriate and learner-centered educational content; and developing effective smart devices-based learning and teaching pedagogies.

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Acknowledgement:

The researcher acknowledges the Diversity Education Institute (DEI), a non-governmental organization based in the United States of America, with branches in Africa, for their support.