Journal of
Education and Practice
(JEP)

SYSTEMATIC LITERATURE REVIEW OF INTERVENTIONS SUPPORTED BY INTEGRATION OF ICT IN EDUCATION TO IMPROVE LEARNERS' ACADEMIC PERFORMANCE IN STEM SUBJECTS IN KENYA.

Prof. Jimmy. Macharia, PhD

Associate Professor of Information Systems &Technology,

Department of Computing, School of Science & Technology,

United States International University -Africa

kmacharia@usiu.ac.ke

Abstract

Poor Learners' Academic Performance in Science, Technology, Engineering & Mathematics (STEM) Subjects has become one of the main problems of education systems in many countries and worldwide learning institutions. They are expected to become more common in the forthcoming decades. This article aims to provide a systematic literature review and a descriptive evaluation of the interventions supported by the integration of information and communication technology (ICT) in education to improve learners' academic performance in STEM Subjects. This paper adopted a systematic literature review of five databases namely: -Emerald, EBSCOhost, JSTOR, Wiley Online, and Taylor & Francis. The paper provides a quantitative and qualitative description of `critical studies about Interventions Supported by Integration of ICT in Education for the Improvement of Learners' Academic Performance in STEM Subjects in Kenya. The following factors were considered for the analysis: teacher's plausible skills capacity interventions, Access to ICT in Education, and availability of digital content in the cloud. The systematic review demonstrated that interventions supported by the integration of information and communication technology (ICT) in education to improve learners' academic performance in STEM Subjects have several gaps that need to be addressed to make them more effective. Study findings show varying perspectives regarding ICT integration in STEM subjects. ICT access, skills capacity interventions, and access to cloud digital content pose a challenge in teachers' pedagogical practices, affecting learner performance. Despite the comprehensive literature search and review across geographical regions within limits of time and access, it is clear that the study findings prepare the ground for further research and the possibility of capacity-building interventions,

This paper has established a need for a more effective pedagogical design promoting technology-supported collaborative learning to prepare learners for the twenty-first century STEM subjects. Further, this study recommends future studies to evaluate interventions to overcome barriers, including teacher access to ICT Education in parts of the world, technology infrastructure, software, and relevant teacher training curriculum for STEM competencies. In addition, further work is required to address the challenge of the glaring lack of access, relevant content, and the necessary infrastructure for digital cloud solutions, particularly with rich STEM subjects' content.

Keywords: *ICT Integration, STEM Subjects, Digital Library, Education, Teaching, Learning*.

1. Introduction

Information and Communication Technology (ICT) includes computers, mobile phones, the Internet, and electronic networks and delivery systems such as radios, televisions, and projectors, among others, and is widely used in today's education field (Fu, 2013). In Africa, strategic response to the teaching of Science, Technology, Engineering & Mathematics (STEM) subjects with the vigilance of integration of Information and Communication Technology has been on the course (Barakabitze et al., 2019). However, progress is being hampered by challenges related to teacher attitudes, beliefs, perceptions, STEM infrastructure, technology access, and teaching skills required to integrate ICT in education (Guler et al., 2019). In East Africa, several initiatives have been explored to revamp the learning of STEM subjects. However, the industries have faced several challenges related to teaching skills and preparedness; poor infrastructure for teaching STEM subjects and low level of Technology access (Joubert et al., 2018). In Kenya, there is evidence of the struggle with the teaching of STEM subjects despite efforts by the government to train primary and secondary school teachers; a case in point is the baseline survey results showing poor performance in these subjects in Kakamega, Vihiga, and Kisumu counties ((Ndiku et al., 2020).

2. PROBLEM STATEMENT

Like many poor developing countries, Kenya faces low performance in STEM and English language subjects, similar to many nations across the globe. Despite the efforts made over the years by the Kenya government and other players in the education space, reports by the Kenya National Examination Council (KNEC), (2018, 2019) have persistently established a declining trend in the performance of many of the STEM subjects including: mathematics, biology, chemistry, physics, and agriculture. Experts assert that if this phenomenon is not addressed, it will have far-reaching consequences for national and social development, such as a shortfall in STEM-qualified professionals in the future (McDonald, 2016). For example, the mass failure in biology in the 2018 KNEC examinations had prior researchers asking, "Where will our doctors come from?" One local daily newspaper had a heading in its education column reading, "Biology Performance Dips, Jeopardizing Medicine Programs" (Alneah, 2019). The performance in other subjects is not any better. Table 1 summarizes the Kenya National Examination Mean Score results for selected STEM subjects. From the results, hardly any of the subjects attained a mean score of 45% or above for six consecutive years (Kenya National Examination Council (KNEC), 2019).

Table 1: Kenya National Examination Mean Score Results for Selected STEM Subjects

Year	2013	2014	2015	2016	2017	2018
Mathematics	27.6%	24.0%	26.9%	20.8%	25.5%	8.7%
Agriculture	33.6%	41.5%	44.8%	30.9%	27.4%	30.3%
Physics	40.0%	33.8%	43.7%	39.8%	35.0%	34.3%
Chemistry	24.5%	32.2%	34.4%	23.7%	24.0%	26.9%

(Kenya National Examination Council (KNEC), 2018*; Kenya National Examination Council (KNEC), 2019)*

Further, the results shown in Table 1 reveal a general declining trend in the mean score of mathematics to a disappointing low of 8.7%. The trend in the other STEM subjects is no better. Taking physics as an example, Figure 1 illustrates a general declining mean score with lows of 34% in 2018.
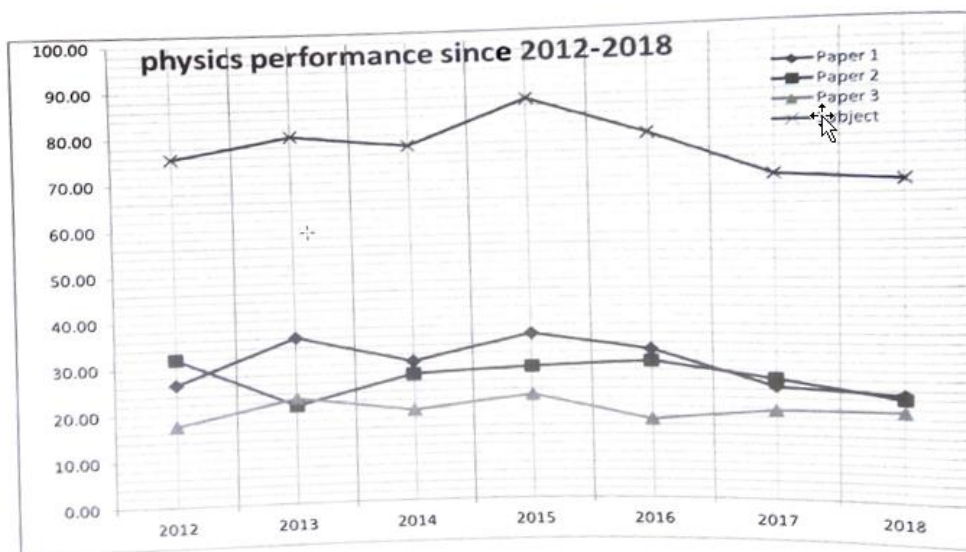

Figure 1: Physics Mean Score: 2012-2018 (Kenya National Examination Council (KNEC), 2019)

Despite capacity-building efforts and interventions in skills and pedagogy related to teaching STEM subjects in Kenya, such as strengthening Mathematics and Science Education (*SMASE*), In-Service Education and Training (INSET) (Joubert *et al*., 2018), unsatisfactory performance has been registered in these subjects in National examination results(Ochich *et al*., 2018). For instance, in 2017, 545,014 candidates sat for Biology, but only 1,503 scored C+ and above. In Mathematics, out of 609,495 candidates, only 3,926 scored C+ and above. In Chemistry, 606,006 candidates sat for the exam, but only 54,925 scored C+ and above. Further, in 2018, for Mathematics, out of 653,549 candidates, 98,219 scored C+ and above. Out of the 584,924 candidates in Biology, only 33,126 scored C+ and above. Similarly, in Chemistry, out of the 650,898 candidates who sat for the exam,

only 73,566 scored C+ and above (Ndiku *et al*., 2020). Further, integration of ICT use in education has been propelled through National policy for using ICT, Particularly through programs such as Computers for Schools in Kenya, ICT equipment for schools, NEPAD e-schools initiative, and School Broadcasting. However, amidst a myriad of challenges, these initiatives have sluggishly met the set objectives, one of which is the integration of ICT in teaching and learning (Barakabitze et al., 2019).

There is extensive research in the area of STEM education and the integration of ICT in schools across the world. These studies largely focus on teachers' Pedagogical Beliefs on the Use of ICT Integration in the Teaching of STEM subjects ((Margot & Kettler, 2019; Madani & Forawi, 2019; (Kurup et al., 2019). The studies point to teachers' absolute belief and intention to acquire the necessary skills through training and the view that in-service professional training will increase their capacity to influence learner performance positively. Additional research on Teachers' ICT skills dap and its Integration in STEM education ((Kurup et al., 2019). Barret *et al*., 2019; Hennessy et al., 2010)) show that a skills gap exists among teachers across continents in terms of ICT skills and integration in their teaching pedagogy and that teacher training does not keenly focus on computer skills and especially those related to STEM teaching. On the other hand, challenges and barriers to appropriate STEM subjects' pedagogy, skills, and competencies are associated with teachers' Access to ICT (Mua Rodanny Kennah, 2017b; Ullah et al., 2019; Ishaq et al., 2020). Additionally, limited access to digital content as well as to iCloud repositories is a barrier to teachers' advancement in pedagogy (Walker, Cammy, Ellis, & Seibert, 2011; Bamgbade et al., 2015; Wangila, 2014). Consequently, this paper intends to bridge this study gap and provide insights on interventions in terms of capacity building in pedagogy for STEM subject teachers in Kenya. This paper aims to carry out a systematic literature review on the Influence of Pedagogy and Integration of ICT in Education on Science, Technology, and Engineering & Mathematics (STEM) Subjects' Learners' Academic Performance in Kenya. The study also purposes to pave the way for an empirical survey to inform capacity building interventions in STEM pedagogy and ICT integration in education in Kenya

A systematic review needs to have a focused, well-defined, valuable, and notably answerable question(s) (Shrestha, 2021). Based on the introduction and problem statement above, ensuing questions that have been addressed to unveil underlying problems and novel interventions for the poor performance of learners in STEM subjects in Kenya entail:

1. Does the teacher's plausible skills capacity interventions on ICT integration in teaching STEM subjects influence students' academic performance?
2. To what extent does Access to ICT in Education in teaching STEM subjects influence students' academic performance?
3. Does the availability of digital content in the cloud on ICT integration in teaching STEM subjects influence students' academic performance?

3. THEORETICAL ANALYSIS

According to Hunter, (2017) prior studies interventions focusing on pedagogy have reported findings founded on traditional psychology theories. These theories are related to behaviorism and

constructivist theories. However, Hunter, (2017) continues to emphasize that the use of High Possibility Classrooms (HPC) as a new conceptual framework for technology integration has taken the Technological Pedagogical Content Knowledge (TPACK) framework. HPC is established from research on exemplary teachers' knowledge of technology integration in Australian primary and secondary school classrooms(Hunter, 2017; 2015). The framework's five conceptions of theory, creativity, public learning, life preparation, and contextual accommodations form an evidence-based scaffold that reflects these teachers' knowledge of technology integration in action. Each conception is underpinned by themes of pedagogical strategies and students' learning processes, as depicted in Table1.

Table 2. Twenty-two themes of student learning processes and teaching strategies underpinning the HPC conceptions.

Theory-driven technology practice	Creativity for learning through technology	Public learning through technology	Life preparation using technology	Contextual accommodations using technology
Technology drives the construction of learning	Technology boosts creativity	Technology scaffolds performance	Technology operationalizes the real world	Technology remains personal and professional
Technology enhances purposeful teaching	technology creates opportunities for production	Technology changes outcomes	technology gives voice	Technology changes time
Technology focuses planning	Technology unleashes playful moments		Technology means ownership and possibility	Technology nurtures community
Technology enriches subject matter	Technology supports values		Technology reveals effectiveness	Technology defines the game
Technology promotes reflective learning	Technology differentiates learning			
Technology shifts conversation and thinking	technology engages students in authentic ways			

Source Hunter (2017)

On the other hand, studies focusing on ICT integration to improve learner performance have adopted several theoretical perspectives. These perspectives include:- the Theory of Reasoned Action(TRA) by Ajzen and Fishbein, (1973) and the Technology Adoption Model (TAM) by Davis, (1989) and

have been used to explore the features that inform user acceptance of a digital library system implementation (Miller & Khera, 2010). TAM2 theorizes that external factors are critical to the perceived usefulness and thus the predictive power of the TAM framework. User acceptance of information technology (UTAUT) by Vankatesh et al. (2003) has also been used to explain Teacher Technology integration in practice.

4. MATERIALS AND METHODS

4.1 Study Design

The systematic literature review (SLR) methodology requires a clear title and objectives with explicit and justified predefined inclusion and exclusion criteria (Shrestha, 2021). This paper adopted a systematic literature review (SLR) methodology following the seven steps of a comprehensive literature review (Onwuegbuzie & Frels, 2016). According to Onwuegbuzie and Frels, (2016), SLR is the integrated process of the seven steps representing a methodology, which yields a synthesis of information that can stand alone as a type of "desk" or can inform primary research.

4.2. Databases and Search Keywords

A systematic literature review of five databases (Emerald, EBSCOhost, JSTOR, Wiley Online, and Taylor & Francis) was carried out related to interventions for learners' academic performance in STEM subjects supported by the integration of ICT in education was carried out in order to obtain articles in English published during the last ten years 2010-2019. An analysis of the articles' references list found in the databases was also performed. The research was carried out at the end of the beginning of 2020. The keywords used to represent interventions, STEM subjects, learners' academic performance, and teachers' ICT skills—availability of digital content and ICT integration in education. The keywords used to refer to ICT were: ICT, Web, mobile applications, informatics, computer-assisted learning, computers, mobile phones, Internet, Smart devices, Tablets, Computer networks, Mobile networks, radios, televisions, and projectors. The search was limited to the abstracts, keywords, and titles of the articles.

4.3 Keywords and Search Terms

The keywords and search terms used in the study include ICT access and integration, Skills capacity interventions, Cloud digital content, and Academic Performance in STEM subjects. These keywords were also searched per the study objectives. The keywords' combinations were done as follows: students' academic performance, teachers' ICT skills gap on the use of ICT integration in the teaching of STEM subjects, and students' academic performance. Other combinations included the teachers' ICT skills gap on the use of ICT integration, students' academic performance, teacher's plausible skills capacity interventions on the use of ICT integration in the teaching of STEM subjects, and student's academic performance; Access to ICT in Education on use of ICT integration in the learning of STEM subjects and students' academic performance. The final combination was the availability of digital content in the cloud, and ICT integration in teaching STEM subjects that influence students' academic performance.

4.4. Inclusion and Exclusion Criteria

Although the search result produced many studies, only the articles that were screened by the inclusion and exclusion criteria were selected for this systematic review. Articles that did not use ICT intensely in the interventions or did not focus on learners' academic performance in STEM subjects were excluded as shown in Table 3.

Table 3: Journal Article Selection Criteria

Inclusion Criteria	Exclusion Criteria
1. Interventions in learner's academic performance in STEM subjects and ICT integration: ICT access, and teacher's Skills capacity interventions, Cloud digital content.	1. Factors other than the indicated interventions aspects were excluded from the study
2. Empirical studies related to learners' academic performance in STEM subjects and ICT integration	2. Other empirical studies related to STEM subjects but outside ICT integration related interventions were excluded
3. Time 2017-2020; cases of lack of more recent studies allowed for some beyond the stated period	3. Periods beyond five years and backward were excluded but only accepted in a lack of more recent studies on a particular construct.
4. Studies with a transparent abstract and quality study methodology	4. Studies without a clear abstract and sketchy study methodology

5. RESULTS

5.1 Geographic Distribution of the Selected Studies

An excel data sheet was prepared for data mining. Each paper was analyzed for the following data: general information, including source and year of publication, country/region/continent, study design, theoretical base, and sample size; result and research reliability.

Table 4: Journal Articles Distribution

Database	No. of studies
Emerald	100
EBSCOhost	60
JSTOR	25
Wiley Online	150
Taylor & Francis	165
Total	500

The data analysis shown in Table 4 indicates that 500 studies from five databases were reviewed and based on key search words; most of the studies were found in Taylor and Francis, while the least were scanned from the JSTOR database. The Emerald database had 100 relevant studies. Therefore, the studies reviewed emanated largely from Taylor and Francis, Wiley online, and Emerald databases, all reputable databases with quality research. This information is illustrated in Table 4. Data analysis and synthesis were categorically done along with the key search words and the associated study objectives. The results of the study are presented in the next session

5.2. Teacher's plausible skills capacity interventions on the use of ICT integration in the teaching of STEM subjects and influence on students' academic performance

Examination of specific studies relevant to capacity interventions on ICT integration in the Teaching of STEM subjects portrays that most of the studies were from Wiley online and Taylor and Francis, which are quality research databases. Figure 6 demonstrates these results. The data analysis shows that 3a total of 60 studies from the five databases was reviewed. These articles focused on teachers' plausible skills capacity interventions on the use of ICT integration in the teaching of STEM subjects and its influence on students' academic performance. One hundred and eighty (180) of the studies were found in Wiley online, while 100 articles were scanned from Taylor and Francis. Forty papers were from the Emerald database, while five articles were scanned from the JSTOR database. Therefore, the studies reviewed emanated largely from Wiley online, Taylor and Francis, and Emerald databases, all reputable databases with quality research. This information is illustrated in Figure 2.
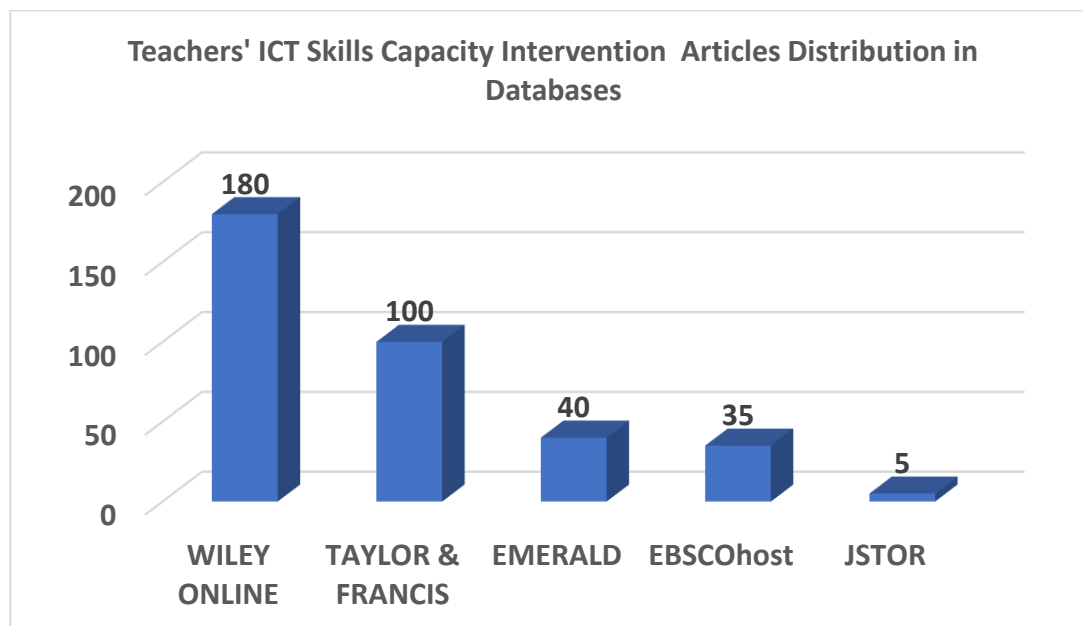

Figure 2: Teachers' ICT Skills Capacity Intervention Articles Distribution in Databases

Some key studies illustrating key findings, ensuing study, and intervention area gaps were summarized in Table 5.

Table 5: Summary of Key Findings on Teachers' ICT Skills Capacity Intervention

Study	Key findings
(Fred Matiang'i, 2017)	Teachers as instructors need to develop STEM-specific competencies. STEM competence covers both the 'know-what' (the knowledge, attitudes, and values associated with the disciplines) and the 'know-how' (the skills to apply that knowledge, taking account of ethical perspectives and values to act appropriately and effectively in a given context)
(World Economic Forum, 2020)	Intervention to align teachers' skills and curriculum to the fourth industrial revolution that requires a rapid response through ICT
(Daly et al., 2009a)	Intervention on teaching skills and pedagogy for STEM subjects require continuous professional development due to constant changes in knowledge content and dynamic technological changes
Capacity Interventions	Interventions including In-service training; provision of ICT infrastructure in schools is needed. MOE - Projects such as National interventions such as the SMASE project at CEMASTEA and INSET for primary school teachers have been intervention avenues for teacher capacity building in STEM subjects
Gap	Robust research gap exists in the evaluation of interventions' impact on student academic performance in STEM subjects

5.3 Teachers' Access to ICT in Education on the use of ICT integration in the teaching of STEM subjects and its influence on students' academic performance

Data collection from various databases on the teachers' Access to ICT integration in teaching STEM subjects was as follows: Emerald **(55),** EBSCOhost **(50),** JSTOR **(5),** Wiley Online **(150), and** Taylor & Francis **(180),** which totaled to 440 articles**.** The data analysis of the 440 studies from the five databases was reviewed. These articles focused on the intervention of Teachers' Access to ICT in Education and the use of ICT integration in teaching STEM subjects, and its influence on students' academic performance. This information is illustrated in Figure 3. Indicates that forty-one percent (41%) of the studies were found in Taylor and Francis, while one percent of articles were scanned from the JSTOR database. The Emerald database had 13%, and Wiley online had 34% of relevant studies. Therefore, the studies reviewed emanated largely from Taylor and Francis, Wiley online, and Emerald databases, all reputable databases with quality research.
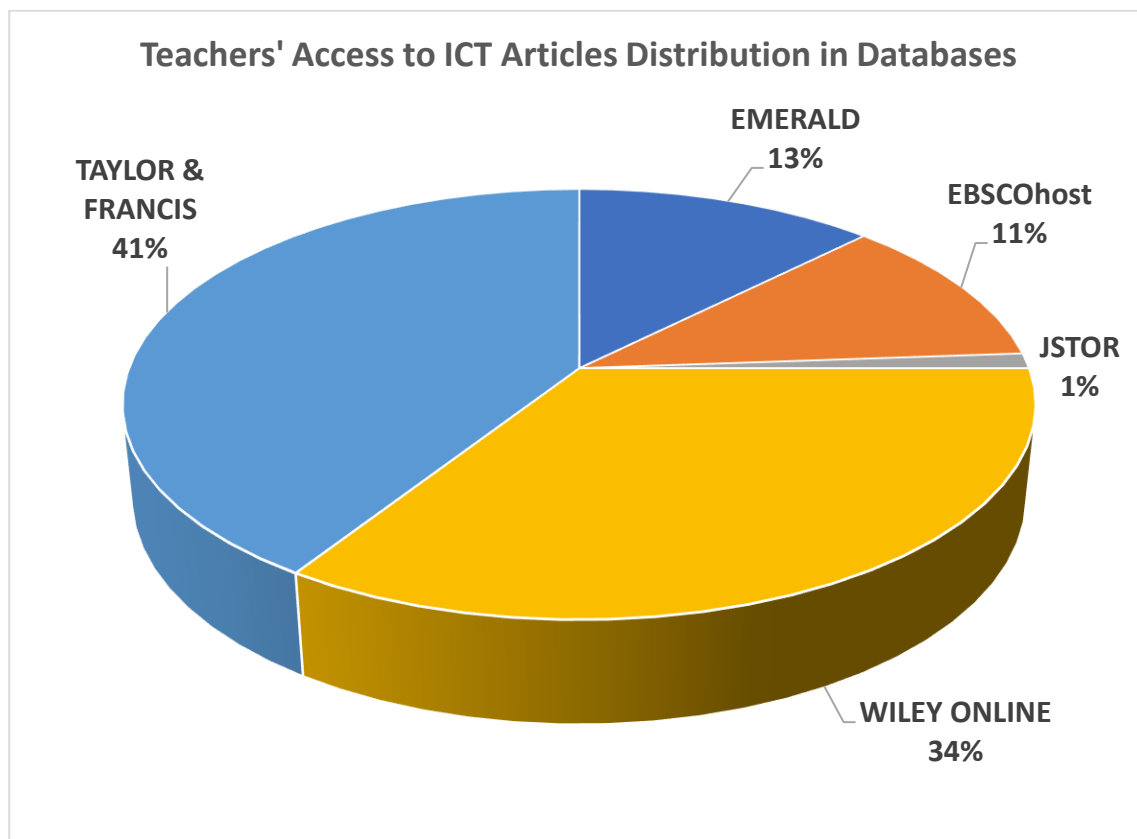
Figure 3: Teachers' Access to ICT Articles Distribution in Databases

Some critical studies illustrating key findings and subsequent analysis and intervention area gaps were summarized in Table 6.

Table 6: Summary of Key Findings on Teachers' Access to ICT Intervention

Study	Key findings
(Mua Rodanny Kennah, 2017)	ICT can be used to remove communication barriers such as that of space and time
(Noor-Ul-Amin, 2013a)	ICTs also allow for the creation of digital resources like digital libraries where the students, teachers, and professionals can access research material and course
(Hooker, 2017);Noor-Ul-Amin, 2013)	ICT eliminates time barriers in education for learners as well as the teacher. It eliminates geographical barriers as learners can log on from any place
Jibrin, Musa, and Shittu, (2017)	The finding reveals that the Internet is one of the beneficial tools in this era of Information and Communication Technology (ICT)

	used in the academic exercise, which cannot be accessed without appropriate ICT infrastructure
Ghavifekr and Rosdy, (2015)	Teachers' well-equipped preparation with ICT tools and facilities is one of the main barriers to the success of technology-based teaching and learning
Ishaq *et al.*, (2020)	Most students and teachers in Pakistan had sufficient Access to ICT tools such as laptops, personal computers at their homes, and computers at their universities, but the printing and scanning facilities were less available at homes
Basri, Alandejani, and Almadani, (2018)	ICT access and adoption resulted in the improvement of the performance of female students more than the male.
Gap	Teacher access to ICT Education in parts of the world, including Kenya, is faced with barriers related to technology infrastructure, software, and relevant teacher training curriculum for STEM competencies

5.4. Availability of digital content Intervention in the cloud on the use of ICT integration in the teaching of STEM subjects and influence on students' academic performance

Data was collected from various databases on the availability of digital content in the cloud on the use of ICT integration in teaching STEM subjects. The papers for this objective totaled 300 articles. The data analysis shows that 300 articles from the five databases were reviewed. These articles focused on the availability of digital content in the cloud, ICT integration in teaching STEM subjects, and the influence on students' academic performance. One hundred and fifty-five (155) of the studies were found in Taylor and Francis, while ten of the articles were scanned from the JSTOR database. The Emerald database had 35, and Wiley online had 85 relevant studies. Therefore, the studies reviewed emanated largely from Taylor and Francis, Wiley online, and Emerald databases, all reputable databases with quality research. This information is illustrated in Figure 4.
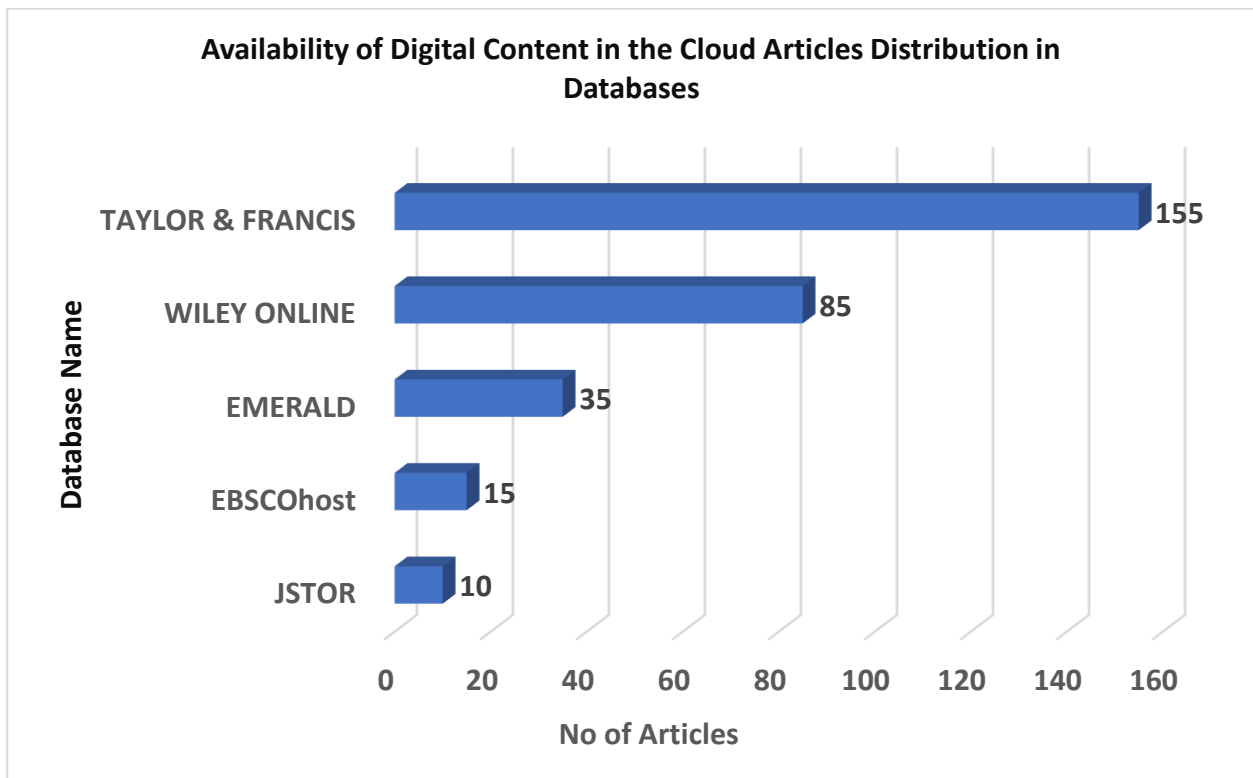
Figure 4: Availability of Digital Content in the Cloud Articles Distribution in Databases

Some critical studies illustrating key findings and subsequent analysis and intervention area gaps are summarized in Table 7.

Table 1: Summary of Key Findings on Availability of Digital Content in the Cloud Intervention

Study	Key findings
(Kumar & Sharma, 2017)	Elaborates on the benefits of cloud computing as a catalyst for STEM education; STEM students can work on authentic solutions within a technology-mediated learning environment while inculcating higher-order thinking skills. In addition, technology-mediated environments support new ideas and real-time collaboration and promote peer learning.
Walker *et al*., (2011) and King *et al*., (2015)	Digital Libraries provide users with coherent access to a very large, organized repository of information and knowledge. Additionally, Digital libraries offer an effective means to distribute learning resources to students and other users.

(Bamgbade et al., 2015; Wangila, 2014)	Integration of the digital library technology with the educational enterprise had come at a similar time when the student requirements for access to library resources also heightened
(Mwakisole et al., 2018)	Digital libraries make learning and access to information very feasible
(Murphy et al., 2019)	Establishes benefits of digital platforms; can help students engage in productive dialogue
Gap	Glaring lack of access, relevant content, and the necessary infrastructure for digital cloud solutions; particularly with rich STEM subjects' content

Although this study mainly focused on studies from the five critical databases, important contributions were also found scantly in other databases such as *the* American Society for Information Science, Library Philosophy and Practice, Information Management journals, and International Journal of Academic Research in Business and Social Science. Kenya Bureau of Standards (KEBS), and Kenya National Examination Council (KNEC), among others.

6. DISCUSSION

6.1 Teachers' Plausible Skills Capacity Interventions on the Use of ICT Integration in the Teaching of STEM subjects and Student Performance

Capacity building and skills development are integral to harnessing the transformative potential of the ongoing development and increasing sophistication of information and communication technologies (ICT) (Cosmas Zavazava, Susan Teltscher, Mike Nxele & Stankovska-Castilla, Letamo, 2018). In the digital era, the demands of the typical student in higher education include the use of ICT in teaching methods, flexible timing and location to complete studies, and the real-world applicability of courses. Such demands pressure universities and other higher learning institutions to introduce new processes and resources. At the same time, teachers may be expected to modify teaching methods without any additional training. However, the content of effective capacity-building programs requires frequent re-evaluation, as new ICT trends and technologies now appear over ever shorter periods. In addition, new challenges for these programs have been presented by the appearance of next-generation networks (NGNs), IPv6, cloud computing, the Internet of Things (IoT), big data, and Artificial Intelligence (AI). Toni Janevski provides an overview of these challenges and an examination of the implications of critical associated issues such as Quality of Service (QoS) and cybersecurity. UNESCO International Bureau of Education, (2019) report on Exploring STEM Competencies for the 21st century points out that effective STEM subject teaching would significantly respond to the United Nations' 2030 agenda for sustainable development. Education, particularly Science, Technology, Engineering, and Mathematics (STEM) education, plays a crucial

role in achieving the SDGs (Kennedy & Odell, 2014) and alludes to the need for capacity building in STEM literacy among stakeholders. Such literacy entails:

- Knowledge, attitudes, skills [and values] to identify questions and problems in life situations. Explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- Understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;
- Awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- Willing to engage in STEM-related issues with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen.

In a fast-changing world, with technology evolving at an unprecedented pace, competence is conceptualized as a developmental capacity rather than fixed skills (Burkhalter et al., 1984); (Marope et al., 2017). Based on these definitions, STEM competence refers to an individual's ability to apply STEM knowledge, skills, and attitude appropriately in everyday life, the workplace, or educational context. Teachers as instructors need to develop STEM-specific competencies. STEM competence covers both the 'know-what' (the knowledge, attitudes, and values associated with the disciplines) and the 'know-how' (the skills to apply that knowledge, taking account of ethical perspectives and values to act appropriately and effectively in a given context) (Secretary et al., 2017)

Editor and learning (2019) propose that an intelligent pedagogy for digital transformation, where artificial intelligence will provide intelligent educational agents, needs to consider how technologies affect perceptions of reality, cognition, and social interactions. Educators today face a significant paradigm shift in the form of the fourth industrial revolution that requires a rapid response through information. In addition, new technologies and infrastructures enable learning to be personalized to each learner.

In Kenya, Capacity Building for Teachers is done through Continuous Professional Development (CPD) to improve the quality of education. This is a planned and lifelong process whereby teachers try to develop their professional and personal qualities and enhance their knowledge, skills, and practice, leading to their empowerment and improvement of their organization and learners. Effective teaching requires considerable knowledge and skills, which should be developed as a teacher's career progresses. The teaching skills and pedagogy for STEM subjects need continuous professional development due to constant changes in knowledge content and dynamic technological changes (Daly et al., 2009b). National interventions such as the SMASE project at CEMASTEA, and INSET for primary school teachers have been avenues for teacher capacity building in STEM subjects; however pedagogical competencies have not been systematically ingrained in teacher training institutes and University education offerings. A robust research gap exists in the evaluation of interventions' impact on student academic performance. Generally, pedagogy in STEM subjects has glaring aforementioned research gaps, which this study endeavors to bridge, particularly in Kenya's context.

The ultimate goal is to bring forth capacity-building intervention through teacher training in pedagogy for STEM subjects.

6.2 Teachers' Access to ICT in Education on Use of ICT Integration in the Teaching of STEM subjects and Students' performance

Information communication technology (ICT) is among the latest innovations that have revolutionized various world operations. It is crucial in education since it has recently created such platforms and opportunities that have facilitated, to some extent, the acquisition of knowledge and teachers and learners. The use of ICT in Education lends itself to more student-centered learning settings. As the world races into digital media and information, the role of ICT in Education is becoming more and more critical. ICT increases the flexibility of education delivery so that learners and teachers can access knowledge anytime and from anywhere. ICTs are said to help expand access to education, strengthen the relevance of education to the increasingly digital workplace, and raise educational quality. The direct link between teachers' ICT use and students' academic performance has been in research focus, with justifications that ICT helps in improving the communication between learners and the instructors (Ishaq *et al.*, 2020)

Generally, people have to access knowledge via ICT to keep pace with the latest developments (Mua Rodanny Kennah, 2017) ICT can be used to remove communication barriers such as that of space and time (Lim & Chai, 2004). ICTs also allow for digital resources like digital libraries where the students, teachers, and professionals can access research material and courses (Noor-Ul-Amin, 2013b). Such facilities allow the networking of academics and researchers and hence sharing of scholarly material. Furthermore, ICT eliminates time barriers in education for learners as well as the teacher. Furthermore, it eliminates geographical barriers as learners can log on from any place (; (Hooker, 2017); Noor-Ul-Amin, 2013).

Jibrin, Musa, and Shittu (2017) investigated the effects of the Internet on students' academic performance in tertiary institutions within Niger State, Nigeria. The finding reveals that the Internet is one of the beneficial tools in this era of Information and Communication Technology (ICT) used in an academic exercise, which cannot be accessed without appropriate ICT infrastructure. However, the study also revealed some of the problems encountered in internet usage, which include slow internet speed and lack of stable power supply. Ghavifekr and Rosdy (2015) studied teaching and learning with Technology and the Effectiveness of ICT Integration in Schools. Findings indicate that teachers' well-equipped preparation with ICT tools and facilities is one of the main factors in technology-based teaching and learning success. It was also found that professional development training programs for teachers also played a key role in enhancing students' quality learning.

Ishaq *et al.* (2020), in a study on The Impact of ICT on Students' Academic Performance in Public and Private Sector Universities of Pakistan, concluded that most of the respondents had sufficient availability of ICT tools, i.e., laptops and personal computers at their homes and computers at their universities, but the printing, scanning facilities were less available at houses, but these facilities could be availed from the university. The majority of the students claimed that they used ICT to perform different tasks, such as preparing assignments and classroom activities and planning their

lessons more efficiently. Basri, Alandejani, and Almadani (2018) focused on ICT Adoption Impact on Students' Academic Performance: Evidence from Saudi Universities. The study also examined the moderators' effect of gender, GPA, and student majors on the relationship between ICT and academic achievement. The findings reveal that there exists a relationship between ICT adoption and academic performance in a conservative environment. An additional finding also stated that ICT adoption improved the performance of female students more than the male.

On the contrary, ICT access is not an obvious key to academic performance. Karamti, (2016) focused on Measuring the Impact of ICTs on Academic Performance: Evidence from Higher Education in Tunisia. Using survey data that involved 377 college students and teachers, a multilevel analysis was conducted to measure the impact of ICT access and use on other student, university, and teacher attributes that may affect academic performance. The results provided evidence for a distinctive, though negative, the effect of ICT on performance. These findings raise questions about the effectiveness of educational policies in Tunisia. The findings also suggest that overall university support is essential in increasing ICT learning impacts. Across divides, studies demonstrate that ICT access is necessary for technology integration in education, particularly benefits rest in teacher's improvement of practice and student democracy in the exploration of knowledge and information. ICT access has been related to good academic performance in different studies with a few contrary results; therefore, this study will test if technology access influences teacher integration of ICT in practice and its effect on student performance in Kenya.

6.3 Availability of Digital Content Intervention in the cloud on the Use of ICT Integration in the Teaching of STEM subjects and Students' performance

In the 21st century, emerging digital content repositories and cloud storage of information have made teaching and learning materials not only more accessible but also available to a wide range of users in a variety of modes. Kumar and Sharma, (2017) concur that Technology integration in the curriculum makes it more exciting and engaging, where students can learn with flexibility in time and place. Kumar further elaborates on the benefits of cloud computing as a catalyst for STEM education:

> *This methodology creates and deepens interest in students towards learning with creativity and innovation.* STEM students can work on authentic and genuine solutions within a technology-mediated learning environment while teaching higher-order thinking skills. Technology-mediated environments support new ideas and real-time collaboration and promote peer learning. *However, cloud computing technology can address affordance as an adoption factor of technology in academics. STEM education on cloud computing technology will gain access to its content-rich features based on flexibility, accessibility, scalability, affordability, reliability, and enhanced agility. The cloud computing-based STEM education infrastructure inculcates development and experimentation skills in students.*

Walker *et al*. (2011) and King *et al*. (2015) concur that "digital Libraries provide users with coherent access to a huge, organized repository of information and knowledge. Additionally, Digital libraries offer an effective means to distribute learning resources to students and other users. However, planning a digital library requires thoughtful analysis of the organization and its users and

acknowledging the cost and the need for infrastructure and ongoing maintenance for continued Access (Bamgbade et al., 2015; Wangila, 2014). Wangila asserts that the integration of digital library technology with the educational enterprise had come at a similar time when the student requirements for access to library resources also heightened. As a result, the development of policies, guidelines, and standards has been common in libraries to ensure professional efficiency and information service quality.

Nazim, (2009) purports that the most critical component of a digital library is its digital collection. Therefore, the viability and extent of usefulness of a digital library would depend upon the critical mass of its digital content. The information content of a digital library includes virtually any kind of electronic media (text, image, graphic, video, etc.) licensed database of journals, articles, and abstracts, and a description of the physical collection. Thus, this wide variety in content and formats have the propensity to catalyze increased use of digital libraries among teachers and students, which is likely to boost academic performance. In a nutshell, from discussed literature, there are undisputed extra benefits of using digital content and embracing cloud computing for storage and preservation, making information accessible anytime, anywhere, and even for simultaneous use by multiple users. Such benefits can be plowed into STEM subject teaching; teachers in professional training and development can access rich content to upskill continuously. On the alternate, teachers who use old "yellow" notes are likely to deliver obsolete information to learners who perform dismally.

7. CONCLUSION

This systematic literature review unravels the fact that pedagogical beliefs of teachers on the use and integration of ICT in teaching STEM subjects are likely to influence their perceptions and practice, whereby negative beliefs may also negatively affect learners' education outcomes. Further, the results of this paper have established that teachers report fairly poor quality and contribution of ICT training during their teacher education. Further, the teachers as instructors need to develop STEM-specific competencies. STEM competence covers both the 'know-what' (the knowledge, attitudes, and values associated with the disciplines) and the 'know-how' (the skills to apply that knowledge, taking account of ethical perspectives and values to act appropriately and effectively in a given context. Teachers' well-equipped preparation with ICT tools and facilities is one of the main barriers to the success of technology-based teaching and learning. This paper Elaborates on the benefits of cloud computing as a catalyst for STEM education; STEM students can work on authentic and real solutions within a technology-mediated learning environment while inculcating higher-order thinking skills. Technology-mediated environments support new ideas and real-time collaboration and promote peer learning.

Digital Libraries provide users with coherent access to a very large, organized repository of information and knowledge. Additionally, Digital libraries provide an effective means to distribute learning resources to students and other users. However, gaps in terms of Digital library characteristics, Digital library access, Digital library subscription costs; Digital library variety in content; Digital library availability of content, and how these variables influence extensive reading culture. Technically lack of technology gadgets, connectivity, and lack of awareness of the use of

digital libraries intervenes against the goal of vast reading culture. Additional gaps alienated include the cost of subscriptions to content sources and limitations in the skill of service providers. More so, the distrust is based on copyright management and plagiarism trends. Finally, limitations also exist in terms of the availability of a variety of content and the linkage between different user needs in different world contexts.

8. RECOMMENDATION

This paper has established that there is a need for a more effective pedagogical design promoting technology-supported collaborative learning to prepare learners for the twenty-first century. STEM subjects have been purported to hold critical solutions to the 21st Century society's needs. Additionally, teacher access to ICT Education in parts of the world, including Kenya, is faced with barriers related to technology infrastructure, software, and relevant teacher training curriculum for STEM competencies. Consequently, future studies may evaluate some interventions to overcome these barriers. Further research and interventions are recommended to overcome the glaring lack of access, relevant content, and the necessary infrastructure for digital cloud solutions, particularly with rich STEM subjects' content. Clearly, from the study results, it is recommended that further comprehensive empirical research be carried out to test the actual influence of the Digital library characteristics on extensive reading outcomes in society and its effect on STEM subjects learners' performance.

Chow and Sajonas (2019); suggest using People-Centered research methods to improve the public Library Experience. Levine-Clark, (2019) projects on a collaborative approach to content collection, while O'Gara and Osterman (2019) advice on the use of Collective Power of the Consortium to transform the Journal Subscription Model to reduce the cost of journal subscriptions. This literature review recommends further studies to explore more digital library characteristics and specific reading outcomes in different contexts. Intervention measures such as capacity building among librarians and other digital library users would be necessary. In addition, in situations of infrastructural challenges such as relevant gadgets to host the digital libraries, interventions in provisions of these gadgets would make digital library content access more practical.

9. LIMITATIONS

The research process acknowledges the databases used and articles reviewed may not be hundred percent representative of all factors and constructs relevant to the study. However, the results resonate with practical experiences on the ground and reasonably provide helpful information for future interventions.

10. REFERENCES

Ajzen, I., & Fishbein, M. (1973). Attitudinal and normative variables as predictors of specific behaviors. *Journal of Personality and Social Psychology*, *27*(1), 41–57. https://doi.org/10.1037/h0034440

Alneah, A. (2019, January 31). *Biology performance dips, jeopardising medicine programmes.* https://www.standardmedia.co.ke/article/2001311503/where-will-our-doctors-come-from

Bamgbade, B. J., Akintola, B. A., Agbenu, D. O., Ayeni, C. O., Fagbami, O. O., & Abubakar, H. O. (2015). Comparative analysis and benefits of digital library over traditional library. *Wsn*, *24*(2015), 1–7.

Barakabitze, A. A., William-Andey Lazaro, A., Ainea, N., Mkwizu, M. H., Maziku, H., Matofali, A. X., Iddi, A., & Sanga, C. (2019). Transforming African Education Systems in Science, Technology, Engineering, and Mathematics (STEM) Using ICTs: Challenges and Opportunities. *Education Research International*, *2019*(February). https://doi.org/10.1155/2019/6946809

Basri, W. S., Alandejani, J. A., & Almadani, F. M. (2018). ICT Adoption Impact on Students' Academic Performance: Evidence from Saudi Universities. *Education Research International*, *2018*. https://doi.org/10.1155/2018/1240197

Burkhalter, B. B., Sharpe, M. R., Halpin, G. M., Schaer, B. B., Curtis, J. P., & Wallace, W. H. (1984). Education for the Future. *Space Education*, *1*(7), 290–295.

Chow, L., & Sajonas, S. (2019). From UX Study to UX Service: Using People-Centered Research Methods to Improve the Public Library Experience. *Public Library Quarterly*, *00*(00), 1–17. https://doi.org/10.1080/01616846.2019.1682884

Cosmas Zavazava, Susan Teltscher, Mike Nxele, H., & Stankovska-Castilla, Letamo, and E. (2018). *Capacity Building in a Changing ICT Environment.* https://doi.org/http://handle.itu.int/11.1002/pub/80f4831e-en

Daly, C., Pachler, N., & Pelletier, C. (2009a). Continuing Professional Development in ICT for teachers : A literature review Caroline Daly Norbert Pachler WLE Centre , Institute of Education , University of London Contents. *WLE Centre, Institute of Education, University of London*, *June*. http://becta.org.uk

Daly, C., Pachler, N., & Pelletier, C. (2009b). Continuing Professional Development in ICT for teachers : A literature review Caroline Daly Norbert Pachler WLE Centre , Institute of Education , University of London Contents. *WLE Centre, Institute of Education, University of London*, *June*.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*, *13*(3), 319–339. https://doi.org/10.2307/249008

Editor, L. D., & Learning, E. (2019). Didactics of Smart Pedagogy. In *Didactics of Smart Pedagogy*. https://doi.org/10.1007/978-3-030-01551-0

Fred Matiang'i. (2017, January). *Strengthening STEM Education in Kenya.* Education News. https://educationnews.co.ke/2017/04/10/strengthening-stem-education-in-kenya/

Fu, J. S. (2013). ICT in Education : A Critical Literature Review and Its Implications. *International*

Journal of Education and Development Using Information and Communication Technology, *9*(1), 112–125.

Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. *International Journal of Research in Education and Science*, *1*(2), 175–191. https://doi.org/10.21890/ijres.23596

Guler, G., Sen, C., Ay, Z. S., & Ciltas, A. (2019). Engineering skills that emerge during model-eliciting activities (MEAs) based on 3D modeling done with mathematics pre-service teachers. *International Journal of Education in Mathematics, Science and Technology*, *7*(3), 251–270.

Hennessy, S., Onguko, B., Harrison, D., Kiforo, E., Namalefe, S., & Naseem, A. (2010). Developing the Use of Information and Communication Technology to Enhance Teaching and Learning in East African Schools: Review of the Literature. *Africa*, *May*, 121. http://www.educ.cam.ac.uk/centres/cce/publications/CCE_Report1_LitRevJune0210.pdf

Hooker, M. (2017). *A Study on the Implementation of the Strengthening Innovation and Practice in Secondary Education Initiative for the preparation of Science , Technology , English and Mathematics (STEM) Teachers in Kenya to integrate Information and* [Queen's University Belfast]. https://pureadmin.qub.ac.uk/ws/portalfiles/portal/130672931/EDD_DISSERTATION_MARY _HOOKER_FINAL_2_.pdf

Hunter, J. (2015). High possibility classrooms: A new model for technology integration. In M. L. Niess & H. Gillow-Wiles (Eds.), *Handbook of Research on Teacher Education in the Digital Age* (Issue April 2015, pp. 466–492). IGI Global. https://doi.org/10.4018/978-1-4666-8403-4.ch018

Hunter, J. (2017). Switching Middle School Teachers onto STEM Using a Pedagogical Framework for Technology Integration: The Case for High Possibility Classrooms in Australia. *Research Highlights in Technology and Teacher Education 2017*, *January 2017*, 37–46.

Ishaq, K., Azan, N., Zin, M., Rosdi, F., Abid, A., & Ijaz, M. (2020). The Impact of ICT on Students' Academic Performance in Public Private Sector Universities of Pakistan. *International Journal of Innovative Technology and Exploring Engineering*, *9*(3), 1117–1121. https://doi.org/10.35940/ijitee.c8093.019320

Jibrin, M. A., Musa, M. N., & Shittu, T. (2017). Effect of internet on the academic performance of tertiary institutions' students in Niger State, Nigeria. *International Journal of Education, Learning and Training*, *2*(2), 57–69. https://doi.org/24924/ijelt/2017.04/v2.iss2/57.69

Joubert, M., Barrett, A. M., Tikly, L., Joubert, M., Angeline, M., Bainton, D., & Cameron, L. (2018). *Secondary School STEM Education for Sustainable Development in Africa Professor Leon Tikly Dr Dave Bainton Leanne Cameron Supporting Secondary School STEM Education for Sustainable Development in Africa*.

Karamti, C. (2016). Measuring the Impact of ICTs on Academic Performance: Evidence From Higher

Education in Tunisia. *Journal of Research on Technology in Education*, *48*(4), 322–337. https://doi.org/10.1080/15391523.2016.1215176

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging Students In STEM Education. *Science Education International*, *25*(3), 246–258.

Kenya National Examination Council (KNEC). (2018). *The Year 2017 KCSE Examination Report with Question Papers and Marking Schemes: Volume 2: Mathematics & Sciences*.

Kenya National Examination Council (KNEC). (2019). *The Year 2018 KCSE Examination Report with Question Papers and Marking Schemes: Volume 2: Mathematics & Sciences*.

King, N., Ma, T. H.-Y., Zaphiris, P., Petrie, H., Hamilton, F., & Trivedi, M. (2015). DigitalCommons @ University of Nebraska - Lincoln Digital Libraries : Functionality , Usability , and Accessibility. *Libraries Without Walls 5*, *May 2010*, 123–131. https://doi.org/10.29085/9781856047876.012

Kumar, V., & Sharma, D. (2017). Cloud computing as a catalyst in STEM education. *International Journal of Information and Communication Technology Education*, *13*(2), 38–51. https://doi.org/10.4018/IJICTE.2017040104

Kurup, P. M., Li, X., Powell, G., & Brown, M. (2019). Building future primary teachers' capacity in STEM: based on a platform of beliefs, understandings and intentions. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-019-0164-5

Levine-Clark, M. (2019). Imagining the Future Academic Library Collection. *Collection Management*, *44*(2–4), 87–94. https://doi.org/10.1080/01462679.2019.1610680

Lim, C. P., & Chai, C. S. (2004). An activity-theoretical approach to research of ICT integration in Singapore schools: Orienting activities and learner autonomy. *Computers & Education*, *43*(3), 215–236. https://doi.org/10.1016/j.compedu.2003.10.005

Madani, R. A., & Forawi, S. (2019). Teacher Perceptions of the New Mathematics and Science Curriculum: A Step Toward STEM Implementation in Saudi Arabia. *Journal of Education and Learning*, *8*(3), 202. https://doi.org/10.5539/jel.v8n3p202

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-018-0151-2

Marope, M., Griffin, P., & Gallagher, C. (2017). Future competences and the future of curriculum:a global reference for curricula transformation. *International Bureau of Education*, 1–60.

McDonald, C. (2016). STEM Education: A Review of the Contribution of the Disciplines of Science, Technology, Engineering and Mathematics. *Science Education International*, *27*(4), 530–569.

Miller, J., & Khera, O. (2010). Digital Library Adoption and the Technology Acceptance Model: A Cross-Country Analysis. *The Electronic Journal of Information Systems in Developing Countries*, *40*(1), 1–19. https://doi.org/10.1002/j.1681-4835.2010.tb00288.x

Mua Rodanny Kennah. (2017). The Use of ICT in the Teaching and Learning Process in Secondary Schools [University of Jyväskylä]. In *Thesis* (Issue August). https://jyx.jyu.fi/bitstream/handle/123456789/51929/1/URN%3ANBN%3Afi%3Ajyu-201611204685.pdf

Murphy, V. L., Coiro, J., & Kiili, C. (2019). Exploring patterns in student dialogue while using a digital platform designed to support online inquiry. *Journal of Interactive Media in Education*, *2019*(1). https://doi.org/10.5334/jime.518

Mwakisole, K. F. ., Kissaka, M. M. ., & Mtebe, J. S. . (2018). Feasibility of cloud computing implementation for eLearning in secondary schools in Tanzania. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT)*, *14*(1), 91–102. https://www.learntechlib.org/p/183558/

Nazim, M. (2009). Managing Digital Library Content: Issues and Challenges. *SRELS Journal of Information Management*, *46*(1), 29–35.

Ndiku, J., Aurah, C., Okoth, T., Ogenga, P., & Ongus, E. (2020). *Baseline survey report on status of teaching and learning of STEM subjects and English Language in pilot secondary schools in Kakamega, Vihiga and Kisumu counties, Kenya*.

Noor-Ul-Amin, S. (2013a). An Effective use of ICT for Education and Learning by Drawing on Worldwide Knowledge , Research , and Experience : ICT as a Change Agent for Education. *Department Of Education University of Kashmir*, *1*(1), 1–13.

Noor-Ul-Amin, S. (2013b). An Effective use of ICT for Education and Learning by Drawing on Worldwide Knowledge , Research , and Experience : ICT as a Change Agent for Education. *Department Of Education University of Kashmir*, *1*(1), 1–13. https://doi.org/6th August 2016

O'Gara, G., & Osterman, A. C. (2019). Negotiating on Our Terms: Harnessing the Collective Power of the Consortium to Transform the Journal Subscription Model. *Collection Management*, *44*(2–4), 176–194. https://doi.org/10.1080/01462679.2018.1564716

Ochich, P., Barasa, I., Otieno, I., Karicho, C., Atamba, A., Ngie, P., Maswai, P., & Gioko, K. (2018). *THE KENYA NATIONAL To be a world class leader in educational assessment and certification To assess abilit ies and certify learner achievements in conformit y wit h global standards*. *June*, 1–48.

Onwuegbuzie, A. J., & Frels, R. (2016). *7 Steps to a Comprehensive Literature Review:A Multimodal & Cultural Approach*. SAGE Publications Inc.

Secretary, E. C., Affairs, G., & Kariuki, S. (2017). *Strengthening STEM education in Kenya*. *June*, 30–31.

Shrestha, B. M. (2021). Principles and Practice of Systematic Reviews and Meta-Analysis. In S. Patole (Ed.), *Journal of the Nepal Medical Association* (Vol. 57, Issue 215). Springer International Publishing. https://doi.org/10.1007/978-3-030-71921-0

Ullah, M. A., Alam, M. M., Shan-A-Alahi, A., Rahman, M. M., Masum, A. K. M., & Akter, N. (2019). Impact of ICT on students' Academic performance: Applying association rule mining and Structured Equation modeling. *International Journal of Advanced Computer Science and Applications*, *10*(8), 387–393. https://doi.org/10.14569/ijacsa.2019.0100852

UNESCO International Bureau of Education. (2019). Exploring STEM competences for the 21st century. *Current and Critical Issues in Curriculum, Learning and Assessment*, *30*, 1–53. https://unesdoc.unesco.org/ark:/48223/pf0000368485

Walker, P. D., Cammy, N. E., Ellis, B. J., & Seibert, K. D. (2011). *O Perations S Kills F or the 21 St C Entury*. *10*, 1–16.

Wangila, F. (2014). An Assessment of the Implementation of Digital Library Technologies in Institutions of Higher Learning: A Case Study of Kenyatta University. *International Journal of Academic Research in Business and Social Sciences*, *4*(9), 532–541. https://doi.org/10.6007/ijarbss/v4-i9/1176

World Economic Forum. (2020). Schools of the future: Defining new models of education for the fourth industrial revolution. *World Economic Forum Reports 2020*, *January*, 1–33. www.weforum.org