

# Harnessing Information Technology for Inclusive Mathematics Education

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## Abstract

*This study is a review on the place of information technology innovations in the delivery of inclusive and equitable quality mathematics education and lifelong learning for all. Specific areas of deployment of IT innovations in mathematics education such as IT-based instructional approaches, open and distance learning, open educational resources, research data mining and virtual learning environments were considered in detail. The implications of these opportunities provided by IT innovations for mathematics education professionals, students, school administrators, and educational policy makers were also discussed.*

**Indexed keywords:** Mathematics education, Information technology innovations, Virtual learning environments, Education for All

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## Introduction

Mathematics plays a key role in shaping how individuals deal with the various spheres of private, social, and civil life. The knowledge and application of mathematics made it fundamental to all facet of human endeavor. Mathematics is the body of knowledge centred on such concepts as quantity, structure, space and change, and also the academic discipline that studies them (Osafehinti,2015). Mathematics can be described as an organized active thinking, which involves the search for patterns and relationship that may be expressed in symbols. It is an expression of the human mind that reflect the active will, the contemplative reason and the desire for aesthetic perfection. Mathematics is essential for the full comprehension of technological and scientific advances, economic policies and business decisions, and other complexity of social and psychological issues.



Mathematics education is a field of study concerned with the tools, methods and approaches that facilitate the practice of teaching and learning mathematics. Mathematics education, particularly at the higher education level, prepares students for quantitative and symbolic reasoning and advanced mathematical skills through general education, services, major and graduate programmes. Odili (2012) argued that mathematicians can be categorized into two groups; the mathematics educators and professional mathematicians. The mathematics educator is concerned with curriculum development, instructional development and the pedagogy of mathematics. Mathematics education basically prepares students to become innovative mathematics instructors, professionally prepared to communicate mathematics to learners at all levels.

Mathematics educators see mathematics not simply as a body of knowledge or an academic discipline but also as a field of practice. According to Kilpatrick (2008) this is because they are concerned with how mathematics is learned, understood, and used as well as what it is, they take a comprehensive view. Mathematics education looks beyond applications to ways in which people think about mathematics, how they use it in their daily lives, and how learners can be brought to connect the mathematics they see in school with the mathematics in the world around them.

Mathematics education as a field of study has been charting the pathways for effective delivery of mathematics instruction since its inception over a century ago (Kilpatrick, 2008). The establishment of national school systems by countries necessitated massive training and re-training of teachers as professionals. Concern for the role of mathematics education in the overall well-being of nations was at its climax at the formulation of the Education for All (EFA) initiative at the onset of the new millennium. The EFA efforts considered mathematics education as a human right, a means of fostering creativity and change, that is, propelling learners into the unknown (Haddad & Draxler, 2002). Over the years, the magnitude of change in the educational system has become tied particularly to rapid innovations in technology.

With the help of technology and radical reimagining of time and space, mathematics education no longer have to adhere to the “one size fits all” approach characteristic of the traditional system (Hampson, Patton & Shanks, 2011). The power of technology is increasingly enabling people to learn and interact, even in the most remote areas of the developing world. Presently, the need for continuous access to information and knowledge makes learning lifelong and the traditionally neat distinction between learning and work disappear. Haddad and Draxler (2002) observed that mathematics education has become a continuum, with no marked beginning and end, which provides opportunities for lifelong learning to help individuals, families, workplaces, and communities to adapt to economic and societal changes, and to keep the door open to those who have dropped out along the way. This ongoing transformation is being reflected daily via instructional organization in mathematics with a concern to foster innovative changes in classroom practices.

This present study intends to present a holistic view of mathematics education delivery for all through information technology innovations. Specifically, technology is viewed here as broadly referring to the group of networks, devices, applications and digital content used to communicate with others and obtain, generate or share information (Broadband Commission Working Group on Education, 2013). The paper first considered an overview of the EFA campaign through the lens of information technology as the determinant of change. Some pivotal information technology innovations in mathematics education were highlighted along with implications for stakeholders in the mathematics education sub-sector.

### **Overview of the Education for All (EFA) Campaign**

The education for all (EFA) initiative is a global movement under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) which focuses on the formal education of children, youth and adults around the globe by the year 2015. The EFA journey began in 1990 at the World Conference on Education for All held in Jomtien, Thailand. ten years later, leaders from all over the globe still gathered at the World Education Forum in Dakar, Senegal, to take stock of progress and reaffirm commitment to the six measurable education goals. Table 1 shows the global Education for All goals and related millennium development goals.

**Table 1: Global “Education for All” Goals (Pre-2015)**

<b>Education for All Goals</b>	<b>Millennium Development Goals</b>
Expand and improve comprehensive early childhood care and education, especially for the most vulnerable and disadvantaged children.	
Ensure that by 2015 all children, particularly girls, children in difficult circumstances, and those belonging to ethnic minorities, have access to and complete free and compulsory primary education of good quality.	Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling.
Ensure that the learning needs of young people and adults are met through equitable access to appropriate learning and life skills programmes.	

Achieve a 50 percent improvement in levels of adult literacy by 2015, especially for women, and equitable access to basic and continuing education for all adults.	
Eliminate gender disparities in primary and secondary education by 2005, and achieve gender equality in education by 2015, with a focus on ensuring girls' full and equal access to and achievement in basic education of good quality.	Eliminate gender disparity in primary and secondary education, preferably by 2005, and at all levels of education no later than 2015.
Improve all aspects of the quality of education and ensure excellence of all so that recognized and measurable learning outcomes are achieved by all, especially in literacy, numeracy, and essential life skills.	

In another stock-taking attempt towards inclusive and equitable quality education and lifelong learning for all, a second World Education Forum was convened in Incheon, Republic of Korea, from 19 – 22 May 2015. At the conference, over 1600 participants from 160 countries, including over 120 ministers, heads and members of delegations, heads of agencies and officials of multilateral and bilateral organizations, and representatives of civil society, the teaching profession, youth and the private sector, adopted the Incheon Declaration for Education 2030, which sets out a new vision for education for the next fifteen years. The Incheon Declaration reaffirms that education is a public good, a fundamental human right and a basis for guaranteeing the realization of other rights. It is essential for peace, tolerance, human fulfilment and sustainable development (UNESCO, 2015). The new vision for education recognizes education as key to achieving full employment and poverty eradication, with focus on access, equity and inclusion, quality and learning outcomes, within a lifelong learning approach.

Perspectives on the EFA initiative recognize that in the twenty-first century, education cannot be separated from technology. Rapid advances in information and

communications technology (ICT) and expanding connectivity to the internet have made today's world increasingly complex, interconnected and knowledge-driven (Broadband Commission Working Group on Education, 2013). Access to quality education for all – which include access to ICT – is an imperative for building inclusive and participatory knowledge societies. Learning, teaching, and assessment enabled by technology require a robust infrastructure consisting of key elements such as high-speed connectivity and devices that are available to teachers and students when they need them (U.S. Department of Education – Office of Educational Technology, 2016). Aside from wires and devices, a comprehensive learning infrastructure includes digital learning content and other resources as well as professional development for educators and policy makers (as depicted in Figure 1).



**Figure 1:** Key Elements in a Technology-Driven Learning Infrastructure (Source: U.S. Department of Education – Office of Educational Technology, 2016)

As seen in Figure 1, the task of setting the vision for technology deployment in education belongs to policy makers within the education sector who are expected to provide the expected leadership for a technology-driven learning infrastructure. The policy makers within government supervising ministries, departments and agencies are required to efficiently communicate this vision to teachers in the field of practice who then implement the vision, undertake quantifiable assessment and pass on feedback for necessary action. The cycle of roles played by these key elements allows for a seamless and profitable technology-driven learning infrastructure.

Considering these dimensions to education, mathematics instruction, which hinges on procedural fluency, conceptual understanding, strategic competence, adaptive reasoning, and productive disposition (Kilpatrick & Findell, 2001) requires an efficient blend with information technology innovations. According to Clark-Wilson, Oldknow and Sutherland (2011), what is needed in schools is student-led mathematical

modelling and problem solving which makes use of the powerful mathematical digital technologies that are widely used in society and workplace. Technological integration in mathematics education has so far enhanced accessibility, considering the open availability of tools and environments that support easy access to content and education for all learners.

### **Information Technology as the Determinant of Change**

The current knowledge revolution is not about how much information is available. It is about how fast knowledge can travel through vast, connected networks of people and how it can grow exponentially (Speer III, 2012). This digital revolution is being fueled by increasing broadband penetration and ubiquity of smartphones, particularly among the new genre of teachers and learners who are successfully imbibing the trendy culture of leisure and school work. Tons of digital content are being turned out by different outlets daily over the internet, with the Computer Science Corp (2012) forecasting an annual increase of 4300% by the year 2020, when the information super-highway will be holding an estimated milestone traffic of 35 Zettabyte of data.

Evidently, information technology is a game changer, changing the educational experience through simulations, games, haptic devices that allows users to “feel”, augmented reality, and more (Oblinger, 2012). Information technology administered in education can deliver content instantly, bring distant individuals together in a collaborative community, and make administrative process faster. Multiple areas of technology impact in education highlighted by Oblinger (2012) include change in the learning experience, guidance and personalization, learner-centred design, research, open solutions, and scaling. These impactful applications of technology in education are gradually closing the digital divide across the globe (Iji, Abah & Uka, 2013; Iji, Abah & Anyor, 2014).

While essential, closing the digital divide alone will not transform learning. Efforts must be made to also close the digital “use” divide by ensuring all students understand how to use technology as a tool to engage in creative, productive, lifelong learning rather than simply consuming passive content (U.S. Department of Education – Office of Educational Technology, 2016). Active use of technology involves the learner driving peer collaboration, design, global connections, interaction with experts, media production, and immersive simulation and coding. Many who advocate rigorous and relevant integration of technology in education often call for comprehensive technology use to develop proficiency in 21st century skills, support innovative teaching and learning and create robust education support systems (Vockley, 2002).

Specifically, 21st century skills as necessitated by the present knowledge society and economy, are expressed in ways of thinking, ways of working, tools for working

and skills for living in the world. According to the Assessment & Teaching of 21st Century Skills (ATC21S) Consortium (2013), skills expressed in ways of thinking include creativity, critical thinking, problem solving, decision making and learning. Communication and collaboration are particular to ways of working since ICT and information literacy are necessary tools for working. Skills for living in the world include citizenship, life and career skills and personal and social responsibility. Optimizing the outcome of technology usage in fostering these skills requires smart partnerships from within and across education that have shared purpose and a strategic and holistic approach, and facilitate change in organizational processes (Voogt&Knezek, 2016). Such smart partnerships aims to deploy technologies to enhance the quality of education, harness technology smartly and recognize the role of technologies in emergent processes.

The reality then is the fact that education is no more a location but a teaching and learning activity. As Haddad and Draxler (2002) rightly observed, in this new paradigm, information technology innovations are supplementing and enriching traditional institutions, delivery systems, and instructional materials in a knowledge infrastructure. This flexibility is essential for non-traditional learners and enables a shift in the engagement of educational institutions in lifelong learning and continuing professional development (High Level Group on the Modernization of Higher Education, 2014).

Innovative technologies have widened the reach of e-learning and online platforms. These new channels of teaching and learning foster compact and efficient course structure, content presentation, collaboration and interaction, and timely feedback (Lister, 2014). They also lead to personal commitment to study and the resulting cognitive engagement with content often contribute to high degree of learning autonomy (Lee, 2016). The opportunities provided mathematics education by these innovations expand growth possibilities for all students while affording historically disadvantaged students greater equity of access to high quality materials, expertise, personalized learning, and tools for planning future education. These technologies, amalgamated by the power of the internet, are the determinant of present trends in education, an indication of the manifesting change in culture and global mindset.

### **Deployment of ICT Innovations in Mathematics Education**

Integrating technology in education is a very sophisticated, multifaceted process, and, just like any other innovation, it should not be introduced without piloting its different components (Haddad & Draxler, 2002). Innovations must be substantiated for appropriateness, suitability, classroom implementability, learning effectiveness, and cost-benefit ratio. With respect to mathematics education, many ICT

innovations have been designed, developed, tested and deployed for use in diverse ramifications. Specific areas of quantifiable success include ICT-based instructional approaches, implementation of open and distance learning (ODL), online instructional platforms, circulation of open educational resources (OERs) and dissemination of research findings.

ICT-based instructional approaches are teaching and learning sequences that make active use of ICT tools to augment the learning experience (Agbo-Egwu, Abah & Abakpa, 2018). There is already a wide range of existing mathematical digital technologies which are readily used by schools all over the world. Clark-Wilson et al (2011) listed innovation-based tools such as dynamic graphing tools, dynamic geometry tools, algorithmic programming languages, spreadsheets, data loggers (motion detectors and GPS), and computer algebra systems (CAS). Computer algebra systems such as Mathematica, Maple, MuPAD, MathCAD, Derive and Maxima have potential to facilitate an active approach to learning, to allow students to become involved in discovery and consolidate their own knowledge, thus developing conceptual and geometrical understanding and a deeper approach to learning (Kumar & Kumaresan, 2008). Abari (2014) observed sustained interest and improved achievement after augmenting instruction in senior secondary school mathematics with Geogebra. Dynamic geometry systems (DGS) like Cabri, the Geometers Sketchpad (GSP) and others, seem to give new dimensions to school geometry, as well as on higher level with a clear invitation to experiment with and explore geometrical constructions and connections (Iji, Abakpa & Age, 2018). Apart from active augmentation of instruction, there is also a new dimension of ICT innovation in mathematics education such as the Class Learning Interactions – Observation (CLIO) tool which enables a systematic observation and monitoring of interactions that take place in the classroom (Manny-Ikan, Tikochinski & Bashan, 2013).

One of the most significant area of deployment of ICT innovations in mathematics education is in Open and Distance Learning (ODL). Leading the pack in this regard is the Massive Open Online Courses (MOOCs). MOOCs are courses designed for large numbers of participants, that can be accessed by anyone anywhere as long as they have an internet connection, are open to everyone without entry qualifications, and offer a full/complete course experience online for free (HOME & OpenupEd, 2015). Details of different dimensions of MOOC are given in table 2. The open University systems of many countries are also driven by a strong pool of technological tools, delivering high-standard skills required for employment and sustainability in mathematics-related careers. ODL programmes are often designed to establish social presence, cognitive presence and teaching presence via the web (Hanover Research Council, 2009). In this regard, even at the early childhood education level, synchronous cyber classroom outperforms all other modes of

instruction in enabling students to simultaneously integrate visual, auditory and kinesthetic processes (Hastie, Chen & Kuo, 2007).

Similarly, crowd-based design activities have been established as a way of supporting student-user mathematical interactions online (Hui, Gerber & Dow, 2014).

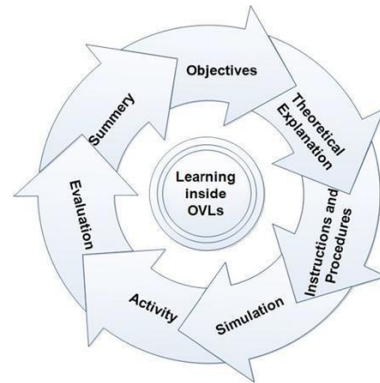
**Table 2: Criteria of Different Dimensions of MOOC**

		Dimension Definition of MOOC	Criteria deciding for a MOOC
M	Massive	An online course designed for number of participants	<ul style="list-style-type: none"> <li>- Number of participants is larger than can be taught in a 'normal' campus class room / college situation (&gt;15 = Dunbar's number)</li> <li>- The (pedagogical model of the) course is such that the efforts of all services (including of academic staff on tutoring, tests, etc.) do not increase significantly as the number of participant increases.</li> </ul>
O	Open	Course can be accessed by (almost) anyone anywhere as long as they have an internet connection.	<ul style="list-style-type: none"> <li>- Course accessible to (almost) all people without limitations.</li> <li>- At least the course content is always accessible</li> <li>- Course can be accessed anywhere as long as they have an internet connection</li> </ul>
		Open to everyone without entry qualifications.	No qualifications / diplomas needed to participate in the online course.
		Course can be completed for free	Full course experience without any costs for participants
O	Online	Complete course online	All aspects of course are delivered online
C	Course	Unit of study	The total study time of a MOOC is minimal
		<p>The course offers a full course experience including</p> <ol style="list-style-type: none"> <li>1. educational content</li> <li>2. facilitation interaction among peers (including some but limited interaction with academic staff)</li> <li>3. activities/tasks, tests, including feedback</li> <li>4. some kind of (non-formal) recognition options</li> </ol>	<ol style="list-style-type: none"> <li>1. educational content may include Video – Audio – Text – Games (incl. simulation) – Social Media – Animation</li> <li>2. offers possibilities for interaction, such as social media channels, forums, blogs or RSS readers to build a learning community</li> <li>3. participants are provided with some feedback mechanism. Can be automatically generated (e.g., quizzes), only by peers (peer feedback) and/or general feedback from academic staff, etc.</li> <li>4. Always includes some kind of recognition like badges or a certificate of completion. A formal certificate is optional and most likely has to be paid for.</li> </ol>

		5. a study guide / syllabus	5. study guide / syllabus includes instructions as to how you may learn from the presented materials and interactions.
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Online instructional platforms are a commonplace for enhancing conversation and collaboration in a mathematical community. Holzl (1999) maintained that in an online learning environment, diversity-bridging tools would include email, bulletin boards, computer conferencing and chat groups. The introduction of other new technologies like the virtual classroom and social media makes it possible to replicate technology-based mathematical experience within and outside the classroom (Hofmann, 2014). A good example of a virtual classroom is Elluminate.Com, which has a very simplified user interface and a robust participant window that shows the name of everyone attending the session, a set of tools to use for interaction such as raising hands to make a contribution to discussions. The instant messaging window allows participants to send messages to other users and the mathematics instructor while the whiteboard is for the instructor to project slides and for learners to write and draw using text and drawing tools. Other widely used virtual learning environments are Moodle and Blackboard.

Most models of instructional platform development are built upon constructivism learning theories with emphasis on fundamental design elements, collaborative elements, selfassessment, team assessment and facilitators' assessment (Koochang et al, 2009). Online content designs often facilitate adaptivity, reuse, modification and alignment with pedagogical theory (Dagger, Wade & Conlan, 2005). For a very practical subject like Mathematics, Ahmed and Hasegawa (2014) suggested Online Virtual Lab (OVL) implementation processes that will result in sufficient training about practical skills, enriched learners' experience, mastery of learning and development of new ideas during training (Figure 2). Such instructional environments, particularly for mathematics, is an integration of technology, content, and people providing learning support, social support and technical support in attaining goals and learning tasks (Chen, 2007).



**Figure 2:** Idealistic Learning Process inside OVL (Source: Ahmed & Hasegawa, 2014)

The rapid flow of information over the internet implies that needed resources for teaching and learning are at the fingertips of teachers and learners alike. Iji and Abah (2016) assert that innovative cloud adoption by educational institutions gives mathematics education students endless opportunities to engage in advanced researches and even in online entrepreneurial outfits. Uncountable research materials can be sourced from synchronized virtual libraries and other linked instructional content repositories. Such readily available support to conventional classroom instruction stands to improve students' mathematical reasoning and problem solving skills, thereby opening up more frontiers for the expansion of knowledge (Agbo-Egwu, Abah & Abakpa, 2018). Open educational resources (OERs) in diverse formats such as playable videos, pdf and MP3 audio files are becoming the backhaul of modern instructional strategies, particularly in flipped learning (Abah, Anyagh & Age, 2017).

Replication of research findings in mathematics education is one of the many success stories of technological innovations in the current era. Methods of instruction delivery tested and reported in geographically distant locations can be adapted in any local classroom in a matter of weeks. This has made the flow of mathematical knowledge more fluid now than ever. More mathematics education research journals are pushing for increased online presence, easing research collaborations and knowledge sharing among academics from diverse culture and backgrounds. Another dimension to this collaboration is the availability of powerful data mining and analytics outfits. Mathematics educators can now seek more robust methodologies for their researches by simply submitting field data to specialist online firms for statistical analysis and interpretations thereby obtaining results that are reliable and valid.

### **Implications for Stakeholders in Mathematics Education**

Information technology innovations tailored to the needs of mathematics education are being birthed on a daily basis. The ubiquity of smartphones (with capacity to run mathematics apps as demonstrated by Agbo-Egwu, Abah & Abakpa, 2018) among students of mathematics education kept expounding the windows of opportunities for key stakeholders. Specifically, these innovations connote deeper reflections for mathematics educators, students, school administrators, and policy makers in mathematics education.

Mathematics education professionals should up their game in terms of creativity, initiatives, and critical thinking. The rate of change in the technological world is too rapid to settle for yesterday's approaches today. Relevance and competitiveness can only be achieved if the sub-sector opens up liaison with IT professionals to keep designing future-oriented technological tools that are dynamic enough to adapt to change. Exploiting all innovative channels entails re-modelling present instruction techniques to reflect the demands of the time. This implies dropping the notion that the continuity function of education has prerogative over the function of fostering creativity and change. Like Haddad and Draxler (2002) observed, modern developments may have eased some burdens, but they certainly have not made life easier for the mathematics teacher. The objectives of education have become more complicated, understanding of the nature of learning has evolved, and the teacher's authority and knowledge are frequently being challenged. Educationists must leverage on available technological innovations to enhance mathematics teachers' proficiency in pedagogical, social, and organizational skills, particularly as they strive to meet the ever-changing needs of the society they serve.

Students in the 21st century have no reason to be left behind in the present knowledge economy. Even among the poorest 20 percent of households around the world, nearly 7 out of 10 have a mobile phone (World Bank, 2016). The emphasis for mathematics education students is on optimum use of digital technologies to drive enriched learning. With the entire world at their beck and call, students at all levels can access mathematical contents to augment their knowledge of mathematics. Students of mathematics education should channel their energies into creative thinking and participate in the rising worldwide efforts to develop mathematical tools that will reshape the landscape of mathematics learning. The trend of web content development enterprises among students should be encouraged by all industry stakeholders. Students can also make use of online instructional platforms to enhance their skills, not only in mathematical proficiency, but also in entrepreneurship and life sustenance.

Considering the global emphasis on international ratings, administrators of educational institutions should make concerted efforts to strengthen technological infrastructures in schools. Primary and secondary schools, particularly in developing countries like Nigeria, should not be afraid of launching carefully planned technological

interventions in the delivery system of basic education. More efforts should be made to design and maintain improved online presence while correcting the impression of negative impact by pushing for directed and weighted information technology usage in mathematics learning.

Policy makers in mathematics education should provide and enforce opportunities for retraining, upgrading and acquiring new knowledge and skills for mathematics teachers at all educational levels. When such mechanisms for capacity development are put in place, it will then be logical to call for enforcement of certification by government-owned educational agencies such as the Teachers Registration Council of Nigeria (TRCN). It will then not be out of place for the critical profession of teaching, like other professions, to demand periodic recertification for mathematics teachers based on evidence of professional upgrading. The quest for standard in mathematics educational practice demands a systemic alignment with the realities of the time through information technology innovations.

### Conclusion

This exposition has attempted to bring to the fore the critical role of information technology innovations in mathematics education. Though issues raised in this review may not be exhaustive enough in view of the versatility of the domain under consideration, they do represent cogent aspects of the trends in technology integration in mathematics education. It is thus emphatic from these deliberations that the reach of mathematics education in the present era is hugely dependent on the pace of creative innovations in IT, particularly, by all key stakeholders in the sub-sector.

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