How to Implement and Diffuse ICT Based Education in Areas with Limited Resources in Developing Countries: Lessons from Rural Kenya

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Abstract--**ICT (Information & Communication Technology) has been touted as having the potential to solve a number of educational issues faced in rural parts of developing countries, however little research has been done to assess the impact of ICT based education on teacher student relationship and interaction. An action research approach is used to explore the impact of introducing ICT as a new learning tool. The findings are used as a guide to determine the appropriate type of ICT tools to be deployed for areas with different resources. A case study done in rural areas reveals the new relationship where students coerce the way lessons are designed and taught, further the research finds that in areas of limited financial resources the DVD based content is the most appropriate methods of executing a lecture style lessons. By designing appropriate methods, this paper also clarifies the barriers to diffusion of ICT in education**

I. INTRODUCTION

A number of issues plague developing countries with social exclusion being the main cause of socio-economic ills. In this regard social inclusion research and policy has gained traction among academics and policy makers in a bid to create a more socially inclusive society. Social inclusion is the process that will enable every person in society to participate in normal activities of societies they live in, including education, employment, public services and social recreational activities [3]. For the development of an inclusive society, preparation of younger generation also needs to be inclusive.

Providing free education is seen as a means of preparing the young generation and in building a socially inclusive society. Siatras and Komuras say that scientific literacy for all" movement can radically overthrow the social obstacles that prevent us from moving towards a democratic and human society [6]. In addition the millennium development goals also ascribe to Universal Primary Education as an important approach to solving a number of social issues, in this respect many developing countries have embarked on approaches of incorporating free universal primary education as national policy [3].

Free education has led to an increase in school enrollment and has subsequently contributed immensely to the expansion of primary school education. However, in many cases the number of enrolling students greatly surpass the available educational resources which has led to an inadequate educational environment, for example it has been established in Kenya, that there is a lack of sufficient number of teachers and textbooks in relation to the number of students, which has consequently created a dissatisfied and demotivated educationalists[10].

II. PREVIOUS RESEARCH

A number of approaches have been initiated in an effort to come up with a solutions to such educational problems faced by developing countries, among these approaches, is the use of information and communication technology (ICT) which is mainly been carried out by simply providing children with PCs and to some extent providing digital books with a hope that it will somehow enhance and improve their learning environment.

A case in point is the Worldreader initiative run by a San Francisco based NGO, that digitally provides a huge library of books to the world's poorest people. Worldreader contends that this is a two-way street in fulfilling their mission of bringing books to all, firstly, relevant content in both English and local languages are made available to students without the high costs and other limitations associated with print media. Secondly, Worldreader assists African publishers to leapfrog into digital publishing by opening up new markets and promoting expanded access by international readers of African stories. [8] In 2010 Worldreader carried out a pilot program in Ghana and Kenya and concluded that even though they participants showed great improvement in reading fluency, their assessment did not registers significant improvement in reading comprehension. [9] In other words the Worldreader initiative even though very important, has not made strides in providing a comprehensive approach in the enhancement of providing a complete thorough learning process.

At the other end of the spectrum is the **Minimally invasive education** (**MIE**) an approach that grew from an experiment done by Sugata Mitra while at NIIT in 1999, often called *The Hole in the Wall.* Minimally Invasive Education in school asserts there are many ways to study and learn. It argues that learning is a process you do, not a process that is done to you.The experience of schools holding this approach shows that there are many ways to learn without the intervention of teaching, to say, without the intervention of a teacher being imperative. [5] The approach as brought to light the importance of having a system where students with different leaning abilities can adopt themselves to their own pace of learning. However, learning is not a process that can be left to its own accord, a certain amount of supervision is required to ensure that the learners even though have different needs in regard to learning, they need to learn systemized content so at to be able to function in accordance with society.

This research also carried out an independent preliminary study that was carried out in Kenya in 2011 to establish the

trends of ICT usage in schools strongly indicated that educationists were very keen in incorporating ICT as a learning tool in the belief that it would help cater to a larger number of students, by providing more digital content in a limited space, that is in the computer.[10] It was also noted that private schools, mostly in the urban areas were already taking initiative of developing ICT based lessons and were making use of the currently available ICT hardware like interactive displays that combines a projector and white board in class sessions.

However, in remote areas and government run institutions, efforts of acquiring ICT related hardware for example electronic terminals were mainly financed through donations, which has proven not to be an effective way of providing ICT based education.[4] It was further noted that there is no clear-cut policy of incorporating ICT into the school curriculum and therefore no research and well-defined evaluations have been done to analyze the impact of introducing ICT into the classroom.

Informed by this, the research set to clarify the best way of initiating ICT based education in areas that have limited educational resources by addressing the following research questions

(i) How can ICT based education be implemented in areas with limited resources and within a constrained budget?
(ii) What kind of social and behavioral changes do teachers and students undergo in the introduction of ICT based education?

III. RESEARCH FRAMEWORK

Lessons in the classroom usually involve the interaction of teachers and students in a closed room. The introduction of a new tool like ICT occasions a renewed perception of how students and teachers relate in the classroom. In order to clarify whether the introduction of ICT elicited any changes in teacher student relationships, this research employed the action research approach to explore the environment of ICT based education especially in a rural setting that is characterized by restricted resources. Action research entails the PDCA (plan–do–check–act) cycle namely the repetitive process of design, implementation, verification, and then making necessary adjustments. In this case, the researchers played the role of coordinator and observed and analyzed the interactions in the class where the teacher functioned as the research respondents and students were the subject of the experiment [2].

Fig 1 shows the PDCA cycle, in the context of implementing an ICT based education the cycle is represents the following stages.

Plan: In this phase the teachers (research respondents) discussed which method would be most appropriate to deliver and ICT based education, that is what lessons and subjects should be targeted and what kind of media to be used. This was achieved through group interview prepare

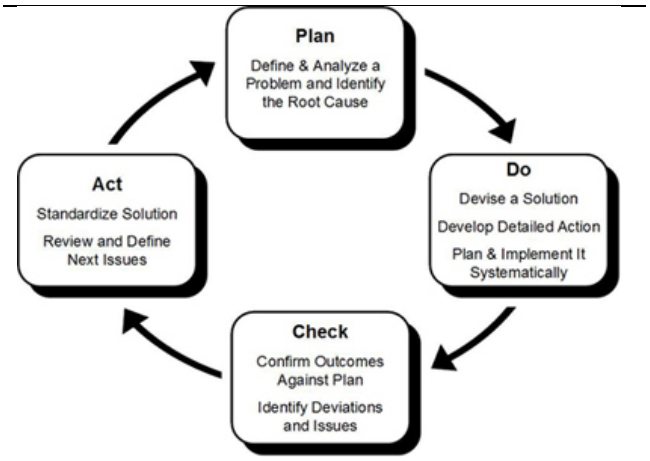

Figure 1. PDCA cycle

Do: Implementing the digital content based on the previously planned lesson. The teachers have understood the teaching purposes and the steps of implementing the instruction correctly. Observations are carried out during the Do stage by the researchers and research respondents (teachers).

Check: After the experiment the researchers give the respondents a semi structured questionnaire followed by discussions stating the experience , achievements or failures of the lessons.

Act: Based on the findings of the research, we propose a system of implementing ICT in rural setting.

IV. OUTLINE OF THE EXPERIMENT

The action research used actual lessons for case studies as the research strategy. By carrying out actual lessons employing ICT based content, it was possible to measure the behavioral changes exhibited by the teachers and students, and also the impact and effects of conducting lessons using ICT. In addition the challenges introduced by using this new approach can be observed and captured for further analysis. All data was quantitative in nature, however data obtained was categorized into two in order to achieve an objective analysis and to compensate for the lack of qualitative data. The first set of data was obtained from observations made during the trail lessons and the second one consisted of the data gathered from the teachers' interview and annotations.

A. Case study

The trial was undertaken in Ndere mixed primary school which is a remote primary school in Siaya county in Kenya. Fig 2 shows a pictorial overview of the school.

The school is characterized by lack of sufficient number of teachers, for example in 6th grade one class consisted of 70 pupils with only one teacher, furthermore the school did not have enough textbooks with one textbook being shared between 3 to 4 students.

Figure 2: Ndere Primary school

TABLE 1. DETAILS ON TARGET SCHOOL

School	Ndere mixed primary school
Student population	556
Teacher population	11
Number of students per class	70（Standard 6 were the trial target）
Number of Computers in school	None
Electricity	Staff room、General hall Regular classrooms do not have electricity

Table 1, shows the number of students against the type of resources available. For this reasons the school was selected as the target of the research since it is representative of kind of school defined in the research question.

B. Methodology

In an interview carried out in April 2013 at Hirayama elementary school in Japan, where the government's ministry of education and other stake holders in the ICT based education are conducting an extensive study in the implementation of ICT tools, it was revealed that ICT based lessons are usually of 3 types, namely, 1) Lecture style lessons, 2) student collaborative style 3) special customized individual lessons and drills. Hirayama elementary school has 240 laptop computers which translate to one computer to three students, teacher prepare lessons plans prior to actual class and appropriate contents is included as supplementary material, in other words ICT is basically a tool used to enhance the content of the planned lesson. [11]

In the lecture style setup, all students view and listen to the same content while the teacher emphasizes and reinforces the main points, in this kind of setup interaction is focused on the teacher and students and the ICT content becomes the medium that facilitates the interactions. In the collaborative setup, a number of students are tasked with solving problems by in cooperating with each other, and subsequently, focus shifts to the interaction among students. The individual based setup primarily involves the interaction between the student and the computer, where specialized content that mainly consists of drills and quizzes are given to the students who try to individually solve the problems. This research focused on designing a lecture style lesson with the aims of lessening the burden of teachers and at the same time to provide learning material to large number of students at the same time.

Initially it was envisioned that the lessons could be conducted through internet by linking a private school with ICT lessons to the remote school. However, preliminary research revealed that even though the GSM system is widespread in Kenya, internet using cables or fiber network is still immature, therefore using modern online based communication systems like skype was not possible due to the slow speed of transmission, in this respect, DVD content was deemed to be the best way of conducting lecture based style

C. Materials used to conduct the trial ICT based lesson

TABLE 2: MATERIALS USED FOR TRIAL

Material (hardware)	Unit
Laptop PC	1
DVD Driver	1
Video / PC projector	1
CRT Monitor	6
VGA splitter	1
UPS	1

D. ICT based trial lesson date and subjects

Video content was developed by a project partner school in Nairobi known as Peace Junior School. Video of mock lessons were taken and converted into DVD format. Math and Science were chosen for mock lessons that were conducted on September 2nd and September 10th to 11th.

TABLE 3 PROFILE OF TEACHERS.

	Math teacher	Science teacher
Teaching experience	6 years	21 years
Number of years at current school	4 years	2 years
Experience with JICA training	None	None

The instructor in charge of the trial had no prior experience using ICT hardware or software, but had acquired a considerable amount of experience in teaching as shown in Table 3. Before ICT based trial class they were given the opportunity to watch the DVD content, in addition in order to capture the interactions taking place while using ICT material, on the 9th of September the instructors was shown how to use and control a video camera so that they were able to take video of the lessons they were carrying out using DVD content.

V. DATA GATHERING

In order to get data about the trial, we conducted, group interviews in-order to obtain teachers opinions on the ICT based trial lessons, in addition a semi-structured questionnaire was developed and sent to the teachers to obtain annotated qualitative data.

A. Data results obtained from interviews

The group interviews revealed the following issues.

1) The teachers expressed concern that even though the introduction of free primary education has led to an tremendous increase of students into the existing schools, the current infrastructure in terms of textbooks, exercise books, desks and teachers cannot meet the needs of the high influx of children admitted into the schools. This has led to using limited resources for an overstretched capacity resulting in provision of poor quality education.

2) In regard to budget the teachers said that desks and chairs are obtained through limited government budget and contribution from the local community. The government's contributions amount to 5 Kenyan Shillings (0.5$) per student per year. The teachers said that this is not even enough to cover for maintenance costs, and is a far cry from the international standard of 96$ per child.[7] The desk were initially designed to sit 2 persons, however after the introduction of free primary education, one desk seats up to 5 students in extreme cases. This crowded condition translates to demoralized students, furthermore the students are not able to fully concentrate on the lesson due to overcrowding. It is interesting to note that there is an initiative by the Kenyan government to provide notebook computers to all primary school children, but the question that begs is where will they place the machines and effectively make use of them.

3) In addition to the ratio of textbooks to student being skewed, there is a tendency of frequently changing the curriculum and in some cases yearly which renders the textbooks used in the previous year useless. Nevertheless, the teachers were quick to add that there is a conceited effort to address the shortage of textbooks, and this year the ratio has improved to 4 students per textbook from last year's 5 to one textbook.

4) In terms of exercise books, the teachers said that in normal situation one exercise book per subject should be provided to students in order for them to take down appropriate notes, however due to limited resources and funding, students are given only 2 exercise books they are expected to use for all the 8 subjects they take.

5) The principal highlighted the fact that currently there are 556 students that are catered for by 11 teachers. The government has dispatched 8 teachers, while the other 3 are paid for by contributions from the local community. In this regard, a class that clearly needs to be split into 2, for example the 4th year students who number 94 have to be taught in one physical classroom, since the school cannot afford extra teachers, and they cannot always depend on the community to provide for their needs.

6) After conducting the lesson, the teachers indicated that in regard to the collaborative style of lesson, students who are able to grasp concepts are tasked with explaining in their own words the same things that other students might find difficult to understand. The teachers think that it is a great way to sharpen the communication skills of the students at an early age.

7) In assessing the DVD content, the teachers were happy with the fact that the DVDs used during the trial lessons were developed in Kenya, and so the students could easily relate with its content, in addition using DVD content is much more cost effective than transmission through the current mobile network system, and DVD can be used over and over again.

B. Observation of the lecture style class

Table 4 underlines the results of the observations done during the ICT based trial lessons. The teachers highlighted the fact that in the lecture style classes done for both the math and science classes, the students showed great interest in the lesson to the extent of even sharing the experience with their guardians when they returned home. It is worth noting that even if there was no teacher in the classroom during the DVD lesson, the students paid attention to the content being shown on the screen.

TABLE 4. OBSERVATION RESULT

Date	Subject	Topic	Lesson style
2013/9/2	Math	Bisecting a line	Both teacher and students first watched the video together, then the teacher followed up with a Q&A session
		Constructing a perpendicular line	Students watched the video with the guidance of the teacher stressing the main points and conducting simple oral quizzes
	Science	Force	Students watched the video with the guidance of the teacher occasionally stopping the video to stress the main points and conduct simple oral quizzes
		Motion in objects	
2013/9/10	Math	Geometry Angles	Both teacher and students first watched the video together, then the teacher followed up with a Q&A session
		Supplementary and Complementary Angles	Both teacher and students first watched the video together, then the teacher followed up with a Q&A session
	Science	Solar System	Students watched the video with the guidance of the teacher occasionally stopping the video to stress the main points and conduct simple oral quizzes
		Weather	
2013/9/11	Math	Circles	Both teacher and students first watched the video together, then the teacher followed up with a Q&A session
	Science	Drainage	Students watched the video with the guidance of the teacher occasionally stopping the video to stress the main points and conduct simple oral quizzes

C. Analysis of the interview and semi-structured questionnaire

The teachers indicated that they had drastically changed the way in which they conducted the classes using the DVD content as opposed to the conventional way of teaching, especially after observing the videos of taken of the ICT based trial classes and seeing the student reaction and increased interest in learning.

The teachers believe that the new found interest, curiosity and appetite for learning was enhanced with the introduction of DVD content. They observed that the students were more attentive to the video lessons as witnessed by how they engaged in a more active question and answer sessions with the teacher. On the other hand, the teachers also said that they were also enthusiastic about the lessons brought about by the increased student interest and also the ICT method brought about a new experience of teaching, rather than the conventional teacher knows it all style. A summary of the discussions that took place are shown in Table 5 which points to the fact that the teachers expressed both a change in their way of teaching and were also able to detect a change in student attitudes towards learning, this in turn motivated them to teach despite being overloaded with work and also the student reactions encouraged them to improve on their teaching methods.

VI. ANALYSIS AND DISCUSSION

This section looks at the changes in behavior brought about by the introduction of ICT tools for use in the classroom. Previous research has focused on the performance brought about by the introduction of ICT based education, on the other hand the impact on teacher and student relationship brought about by the introduction of ICT has not been addressed and therefore appropriate ICT content and policy has not been fully developed.

In this research The use of DVD in lecture style class setup was intended to reduce the burden of teaching a huge number of student, however it was noted that this was not the main issue but rather the students and teachers showed changes is the way they interacted in class。

Using ICT requires the teacher to carry out a lot of prior lesson planning which actually translates to more work for the teacher, however, the teacher was able to have a different perspective on how to prepare for lessons and consequently the teacher had a different approach towards education as a whole. The teachers also expressed the fact that they personally experienced remarkable improvement and growth and were motivated to teach owing to the new ICT tools introduced. This shows that the reforming teaching methods and fostering motivation can be achieved through the introduction of an innovative tool, even when resources are stretched and teachers are overloaded with work.

TABLE5 SUMMARY OF ISSUES RAISED DURING GROUP INTERVIEWS

Issue raised in using ICT content.	Math	Science
What do you think of using ICT material in the classroom		Apart from being an eye-opener to me, it was a learning experience to me too. The actual use of computer (e-learning) in an ordinary local school in a rural set-up made me feel great and thus my self-confidence and self-esteem was greatly boosted. I believed more in myself as I manipulated the computers and other gadgets as the lessons progressed. It led me towards thinking outside the box even more than before
What changes did you realize	Students were able to grasp concept much easier as they could actually see materials like compass and rulers being used in actual setting. The remote schools cannot afford these basic materials.	The pupils were more open and ready to learn using the videos. Most had positive attitude towards it and this was quite encouraging. The pupils were more eager to learn more since they were so keen so as not to miss a lot from the computer-based lessons.
What was the difference in students between the classes conducted without ICT and classes done using ICT	By-and-large they realized their greatest fears were turned into nice learning experiences both by the way I introduced them to e-learning and the actual content and concept they got from the computer software specially designed for their level. Through their learning sessions, the pupils were able to learn a lot and thus it made me, as the teacher, to meet my lesson objectives more easily than before. I realized that even slow learners could move at an increased pace compared to their normal pace.	
Any other comments for ICT class ?	I would like to continue using the ICT based materials, and if possible participate in the development of the content.	Even though I am not computer savvy, I found the content easy to use, though I would like to see more content developed and I think I can assist in the production of DVD content

These behavioral changes were witnessed from the first lesson using ICT based trial lesson that was carried out on September 3rd and the second trial lesson carried out on September 9th and 10th. The main reason that there was change in the interactive behavior is because the students renewed interest in learning prompted the teachers to change their way of teaching.

In other words, the introduction of ICT based learning elicited excitement and a revitalized a new appetite for learning among the children, this in turn drove the teachers to change their ways of teaching and subsequently led to increased motivation notwithstanding the large number of students in class.

In retrospect, other renowned teaching methods that aim to improve educational teaching methods in rural areas like the JICA teacher training program, has mainly focused on the teacher led student centered approach,[1] on the other hand, this research revealed that the introduction of innovative tools shifts the focus to a student led student centered approach, where the student is not only the main character, but the also the one who dictates how the lessons is prepared.

Implementation of ICT based on the PDCA cycle

Usually the interaction of a learning process in the classroom is mainly controlled by the teacher, however by introducing the ICT as a tool both the teacher and students undergo a paradigm shift where the teaching method initiated by the teacher is coerced by the student's reaction to the new method. Fig 3 shows that in that the initial phase of introducing ICT, the student reaction, in this case excitement and renewed interest in learning influences how the teacher conducts the class. So even though the lesson is teacher driven, the actions of the teacher are constrained by the reaction of the students. The second phase is feedback, where the teacher makes observations of the ICT based lessons and redesigns the ICT content guided by the reactions and interactions from the previous class. These two phases are then repeated resulting in improved teaching methods and improved ICT content.

However in this research, the contents were developed in a private urban school where facilities and resources are available, and the environment is quite different from a rural setting. Looking at the World reader concept where content is developed by the NGO who are far placed from rural setting, it is observed that the comprehension abilities of the students did not improve, [9] whereas our research showed a great improvement in comprehension and high interest of students and teachers. The MIE approach even though offering a channel of self-learning at individual pace, it does not offer the richness of a comprehensive system that can furnish the learner to be able to function in the immediate community or social setting.

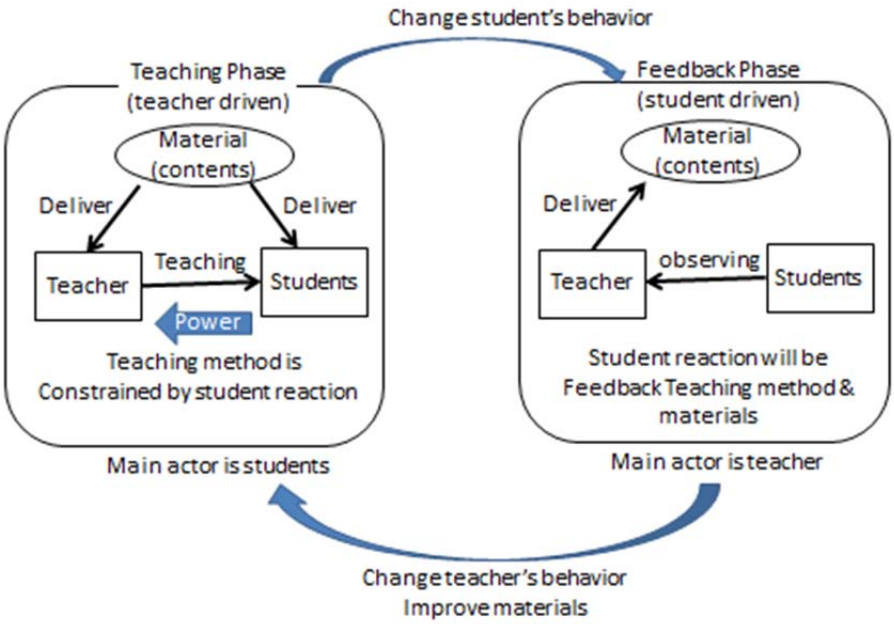

Figure 3

It was initially envisioned that lack of teachers in rural schools and the low motivation of teachers could be replaced by the use ICT tools and ICT based classes, however the introduction of ICT based classes led to an increased interest in learning for the students and increased motivation of the teachers. It is noted that the teachers in rural setting also expressed their intention in participating in content development, however they do not have the knowhow to do so. In this respect it is inevitable to build a teacher content development community to allow teachers a collaboration space aimed at developing content that can be delivered using ICT tools. This collaborative community serves as an environment where participating teachers build their skills and knowhow of developing content.

The research revealed that ICT can also be delivered using the bear minimal components of ICT content for example using DVD based content, therefore the community can be made aware of the changes produced by the introduction of ICT education that was delivered using simple ICT tools that is ICT based education elicits an increased interest to learning both for students and teachers. Therefore community can be encouraged to contribute in the provision of simple ICT tools to the local schools with the aim of increasing the quality of the local education quality. Thus the sustainable provision of ICT based tools can be achieved through increased participation of local community.

VII. CONCLUSION

This research employed the action based research, where actual participation of subjects was undertaken in the classroom and observations were made on the changes in interaction and perception brought about by the ICT tools. The observations showed that apart from alleviating the problems associated with limited resources and overburdened teachers, the introduction of ICT based learning significantly leads to change in student and teacher perception and interaction in the classroom, furthermore it triggers renewed effort towards teaching, subsequently increasing the motivation of overburdened teachers.

The introduction of ICT based lessons especially in rural areas are best deployed using DVD content, due to limited resources. Rural schools are not able to afford the comfort of supplying all students or with computers and therefore the DVD content is used in lecture style setup, can catered for an environment with many students at the same time, this research showed that limited resources in this case a projector with additional monitors and a laptop can be used to deploy an interactive lesson to many students at the same time even when there is not teacher in class. Furthermore as earlier discussed, teachers from rural areas should be included in the development of content in lieu of their proximity to the students, a group of teachers directly involved in content development will enhance the sustainability of ICT usage in rural settings. In addition, involving local educationist in content development will have the compound effect of attracting facilities and resources from the local community. This involvement of local community is also key to ensure the sustainability of providing continuous ICT education to schools in rural settings.

This research made use of qualitative data, further research incorporating quantitative data should be undertaken to make statistical claims. In addition, more comparative studies should be done between development and implementation in rural areas vis a vis the development and implementation in urban schools in order to make solid

claims especially with the inclusion and participation of local communities that can lead to clear analysis that can be used by educationists and policy makers in developing countries.

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