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Development of an Impact Assessment Algorithm for the Adoption of Information and Communication Technology in Basic Education using Cross-Impact Method

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Abstract— In many countries, the adoption of Information and Communication Technology (ICT) in basic education has been continuously linked to higher efficiency, productivity, and educational outcomes, including quality of cognitive, creative and innovative thinking. This paper focuses on the development of an impact assessment algorithm for evaluating the adoption of ICT in basic education using Cross-impact method. A questionnaire on adoption of ICT in basic education was designed based on Government Policy (GP), Teacher Competency (TC), Availability of ICT infrastructure (IF), Integration of ICT in school curriculum by Ministry of Education (MC), Student preparedness in adopting ICT in learning process (SC) and Perception of schools' management in adoption of ICT in schools (MI), which are the six major events considered. The questionnaire was administered to experts in basic education within the selected South-Western states of Nigeria (Oyo, Lagos and Ekiti). Experts' opinions from the administered questionnaires were quantitatively analysed using descriptive statistic in Statistical Package for Social Sciences. The results obtained from the analysis of questionnaires were used to derive the Initial Probability (InitProb) and generate the Conditional Probability Matrices (CondProbMatrices) for occurrence and non-occurrence of the six events under consideration. The impact assessment algorithm was developed such that its starting instructions would determine the consistence of the InitProb and the CondProbMatrices using the three fundamental laws of probability calculus (Normalization, Product and Addition rules). These are followed by sequential instructions which would determine the occurrence of each event in the CondProbMatrices. Then, through repetitive instructions, each event would be selected at random and its occurrence and non-occurrence would be determined using a random number generator. The last group of instructions would successively determine the impact of each event on other alternative events. Thus, the developed impact assessment algorithm could replace the existing user perspective method of evaluating the adoption of ICT in basic education.

Keywords— Impact assessment algorithm, Basic education, Event, Adoption of ICT, Instruction

I. INTRODUCTION

Studies have established the roles of ICT in achieving quality education at all levels of the school system. ICT is seen as a key tool in acquiring, processing and disseminating knowledge [1]. It offers increasing possibilities for codification of knowledge about teaching activities anywhere, anytime [2]. Other researchers have also argued that ICT has the potential to transform learning environments and improve the quality of teaching [3], providing access to richer environment [4], increasing opportunities for active learning, inter connectivity and feedback [5], enhancing motivation to learn [6], and having a positive effect on students' achievement in different subject areas [7]. Thus, in addition to the benefits associated with the practical application of ICT in the achievement of 'Education For All' (EFA) goals and especially in the context of Nigeria's UBE, it is equally important to develop an algorithm that could assist in assessing the effect of integrating ICT in Education.

Nigeria, like many other countries around the world, has over the years sought to improve her educational system by introducing reforms and making plans based on the educational needs of the country; hence, the development of Universal Basic Education (UBE). The broad aim is to give a foundation for lifelong learning through the inculcation of appropriate learning-to-learn, self-awareness, citizenship and life skill (Federal Government of Nigeria [8]. With this focus, it can be concluded that beyond increasing access to education, ensuring quality is a key goal of basic education in Nigeria In 2000, the international development community adopted the Millennium Development Goals (MDGs) that aims at eliminating global poverty, hunger and inequality by 2015 [9]. Education receives special attention in MDGs, which focuses on enhancing primary education in terms of quality and access. Information and communication technologies (ICTs) can be used to achieve the MDGs and the 'Education for All' principles described above as they can enhance the quality of education across the board of primary, secondary and tertiary level to support teacher training.

Information and Communication Technology (ICT) in education has been continuously linked to higher efficiency, higher productivity, and higher educational outcomes, including quality of cognitive, creative and innovative thinking. As early as 1983 in Australia, a Commonwealth Schools Commission was established, which recommended that schools should provide all students (Years 2-12) with at least 30 minutes hands-on experience with computers per week, and that every school should have at least one teacher with sufficient computer competence to advise other teachers [10]. Likewise, Nigeria developed an ICT policy in 2001, one of the objectives of the policy focused on integrating ICT into the mainstream of education and training, including basic education. Quality improvement has two important dimensions: to increase in the amount of subjects covered by existing curriculum and through better pedagogy (changes in the learning process). The later includes developing new types of learning; ability to gather and manipulate information, problem solving, higher order thinking, critical and creative thinking and other necessary skills to interact in knowledge based economies. The need for the changes in the learning process paved way for ICT use in the teaching and learning processes where students are expected to play more active roles than before [11].

Forecasting is a process that predicts the future. Good forecasting can give more bases to making decisions and avoid risks [12][13]. To forecast the future of an event, a number of forecasting approaches have been introduced and they can be divided into four groups: 'Explorative', 'Comparative', 'Causal models' and 'Probabilistic method' [14]. These approaches were combined and adapted to the nature and to the quantity of data available. The Cross-impact method is a methodology for forecasting which draws its strength from the recognition of mutual effects between events and developments. Nevertheless, this paper entails the development of an impact assessment algorithm that assessed the impact of adopting Information and Communication Technologies (ICTs) in basic education using South-West Nigeria as a case study.

II. RESEARCH METHODOLOGY

A. Delphi Study

Delphi study was used in this work to survey and collect the opinions of experts in educational system to get their opinion as touching the adoption of ICT in teaching and learning activities. The processes involved in the study are as follows.

1) *Gathering and Formulation of Major Events:* This is the most important, and time consuming aspect of the process; it involves desk/field research activity. Literatures, journals, and textbooks that talked about the integration of ICT in Education were consulted. Federal and State Universal Basic Education Boards were visited to get policy documents that were concerned with adoption of ICT in schools. However, inherent survey was not left out to get related information which was useful in drawing out the conclusion. Therefore, major factor events were filtered out from the numerous events gathered from the literatures, policy documents and survey conducted.

The relevant events for this research work were enlisted below:

i. Government policy
ii. Teacher competency
iii. ICT Infrastructure
iv. Ministry of Education Involvement
v. Student readiness
vi. School Management preparedness.

2) *The Events Definition*: There are many factors that need to be put in place for successful adoption of ICT in basic Education; these factors are referred to as events in this research work. The ones used are briefly explained as follows:

a) The Event 1: The Government policy

For the successful integration of ICT in Education, it is acknowledged that government should create the necessary guiding frameworks (polices and strategies) both at the National and sectorial (education) levels. The ICT in Education policy should be linked to the national ICT policy and vice-versa. In turn, national ICT policies should be rooted in the countries overall development plan.

b) The Event 2: Teacher Competency

This event considers two distinct but related issues with respect to teacher training and ICT. On the one hand, ICT provides support for general teacher training programmes, (pre and in-service) and continuous upgrading programmes, many of which, in the Nigerian context, use distance methods. On the other hand, training of teachers in use of ICT for teaching, in an integrated manner, is an essential component of successful adoption of ICT across the education sector.

c) The Event 3: Availability of ICT infrastructure

Effective ICT integration in schools depends on the available of sufficient physical and technological infrastructure. The physical infrastructure includes learning areas such as classroom, computer labs, dedicated ICT resource rooms and libraries: in short, all of the space and furniture required for ICT enhanced school environment. Technological infrastructure includes interactive whiteboard, computers, video conference system, slate/Tablet, student response system, projector, Digital TV, Digital Recorder, broad-band internet access are technological resources used in education. Therefore, schools need to provide at least basic physical and technological infrastructure if they want to integrate ICTs effectively into teaching and learning process of their schools.

d) The Event 4: Integration of ICT in school curriculum by Ministry of Education

Since the Nigerian educational system is highly centralized, ICT related school policies are linked to National policies as developed by the Ministry of Education (MOE) either Federal or State. The MOE promotes ICT use, but links this explicitly to the prescribed National curriculum, the central examination system and teacher-led didactical strategies. However, an ICT policy does not automatically result in the adoption of innovations unless all stakeholders involved are clearly aware of the policy.

e) The Event 5: Student preparedness in adopting ICT in learning process

The wide use of ICT has been a topic of discussion and concern all over the world, hence, educational systems around the world are under increasing pressure to utilize the new Information and Communication Technologies to teach students the knowledge and skills they require in the 21^{st} century. Therefore, a flexible timetabling system which, can make maximum use of teaching space and encourage innovative approached to delivery is essential if schools management plan to move flexible modes of development and delivery.

f) The Event 6: Perception of schools' management in adoption of ICT in schools

As ICT continues to drive changes in present and future society, school management need to define upfront their organizational vision and actions in view of planned change. A number of studies present evidence that an increase in classroom use of ICT in schools can be linked to a factorable policy environment. School management produces the desirability to build a coherent and supportive community of practice associated with effective, regular and consistent ICT use.

3) Design of the Delphi Questionnaire

In this work, the aim of the questionnaire was to carry out a survey that would capture critical data on the adoption of information and communication technologies in basic education in South-West Nigeria. The Null hypothesis postulated was based on the following:

i. Nigeria government policy in supporting the integration of ICT in basic education in teaching and learning processes.
ii. Availability of ICT infrastructural tools in supporting teaching and learning process in basic schools in Nigeria.
iii. Teachers competency in use of ICT in teaching and learning in basic education in Nigeria.

Face to face interview with the respondents were used during the course of survey. The questionnaire was divided into three stages. In the first stage, experts were asked to provide the initial probability of occurrence of each single event. The judgement referred to the proportion of primary and junior secondary school teachers, Head-teachers, Principals, Inspectors of Education and parents in South West Nigeria that adopted the use of ICT. In the second stage of the questionnaire, experts were asked to indicate the conditional probability of the events, whereby referring to the probability that each of the other events listed were implemented given that selected events turned out to be true (or occurred). Finally, in the third stage, experts were asked to indicate the probability that each of the other events listed was implemented given that event selected did not turn out to be true (or did not occur).

A Likert rating scale is psychometric scale commonly used in questionnaires and is the most widely used scale in survey research. The experts responded to the questionnaire using a Likert probability rating scale ranges from 1 to 5. The meaning of the Likert probability scale follows this trend:

1= (0-10%): Event almost impossible
2= (11-30%): Event unlikely
3= (31-50%): Event equally likely of unlikely
4= (51-70%): Event likely
5= (71-90%): Event almost certain.

B. Procedure for Data Collection

The first part of data collection involved the scientific and purposive sampling of South West states selected. Tables 1, 2 and 3 present the descriptive statistic of South West states and total number of their local government areas, the selection of South West states based on scientific sampling and the selected local government areas in selected states respectively. The target population was from Oyo, Lagos and Ekiti States with 6, 4 and 3 local government areas respectively. A total number of 200 copies of questionnaire were administered via face-to-face interview with the respondents. A total number of 168 questionnaires (84%) were correctly filled, returned and used for this research; the Table 4 showed the numbers of questionnaires administer to each selected states. For instance, 60, 90 and 50 questionnaires were administered while 51, 81 and 36 copies were returned meaning that 85%, 90% and 72% were received from Lagos, Oyo and Ekiti States respectively. Percentage of unreturned questionnaires was 16%.

Table 1: South-West states of Nigeria and number with Scientific Sampling of their Local Government Area.

States	No of LGA	20% of No of LGA
Lagos	20	4
Ogun	20	4
Ondo	20	4
Oyo	33	6
Osun	32	6
Ekiti	16	3

Table 2: Number of Selected Local Government Areas in Selected State

States	No of LGA	No of selected LGA
Lagos	20	4
Oyo	33	6
Ekiti	16	3

Table 3: Selected States with their Local Government Areas

State	Local Govt. Area
Lagos	Ikeja
	Epe
	Badagry
	Lagos Island
Oyo	Ibadan Central
	Ogbomoso South
	Surulere
	Akinyele
	Atiba
	Iseyin
Ekiti	Ado-Ekiti
	Oye
	Ikole

Table 4: Analysis of the Administered and Returned Questionnaires

State	No of questionnaire administered	No of questionnaire returned	Percentage(%) of questionnaire returned	Percentage (%) of questionnaire unreturned
Lagos	60	51	85%	15%
Oyo	90	81	90%	10%
Ekiti	50	36	72%	28%
Total	200	168	84%	16%

C. Characteristics of the Respondents

The participants were selected to be representative of an expert community rather than of the public at large. Therefore, the criteria for the selection of experts were based on the following:

i. The primary school teachers.
ii. The primary school head teachers.
iii. The junior secondary school teachers.
iv. The junior secondary school principals and vice principals.
v. The local inspectors of Education.
vi. The permanent secretaries in Ministry of Education.
vii. The secretaries to the board at Universal Basic Education
viii. Lecturers in departments of computer science, information science and education in tertiary institutions.

The Table 5 presents the demographic information and descriptive statistics of the experts. It shows that both male (61.9%) and female (38.1%) actively participated in the survey with a wide margin in favour of the male counterparts. Majority (44.1%) of experts have educational qualification of first degree and Higher Diploma Certificate (HND), followed by experts (33.3%) with National Certificate in Education (NCE) and Ordinary National diploma. Master degree holders were 14.9% and Ph.D. holders were 7.7%. Lastly, the degree of expertise of the experts were measured, with the results that show that 1.3% were unfamiliar with the topic, 4.6% casually acquainted with the topic, 7.6% familiar, 18.3% knowledgeable and 68.2% expert.

Table 5: Demographic Information of the Experts

ITEM			Percentage (%)
Sex distribution	Female	(64)	38.1%
	Male	(104)	61.9%
Education Qualification	NCE/OND (56)		33.3%
	B.A/B.SC/B.ED/HND(74)		44.1%
	M.SC/M.A/M.ED/(25)		14.9%
	PhD/PROF.(13)		7.7%
Degree of Expertise	Unfamiliar with the topic		1.3%
	Casually Acquainted		4.6%
	Familiar		7.6%
	Knowledgeable		18.3%
	Expert		68.2%

D. Data Analysis

The first step of the analysis is data coding. The data was coded into a format with alphanumerical code using the SPSS. The major events under consideration were coded as follow:
Event 1: Government policy (GP)
Event 2: Teacher Competency (TC)
Event 3: Availability of ICT infrastructure (IF)
Event 4: Integration of ICT in school curriculum by Ministry of Education (MC)
Event 5: Student preparedness in adopting ICT in learning process (SC)
Event 6: Perception of schools' management in adoption of ICT in schools (MI)
The coded events were analysed using descriptive statistics in SPSS. Thereafter, the Cross-impact probability matrices for occurrence and non-occurrence of the events were formulated from the results of the aforementioned analysis. The matrices showed the initial probabilities of events under consideration, the conditional probabilities when the events occurred and the conditional probabilities when the events did not occurred. The matrices were shown in Tables 6 and 7.

Table 6: Cross-Impact Probability Matrix when the Events Occurred

EVENTS	INITIAL PROBABILITIES	GP	TC	IF	MC	SC	MI
GP	0.43		0.60	0.44	0.65	0.64	0.59
TC	0.29	0.44		0.40	0.53	0.56	0.61
IF	0.20	0.65	0.67		0.72	0.71	0.72
MC	0.51	0.64	0.61	0.61		0.66	0.75
SC	0.45	0.41	0.48	0.53	0.51		0.53
MI	0.44	0.53	0.74	0.63	0.69	0.67	

Table 7: Cross-Impact Probability Matrix when the Events do not Occurred

EVENTS	INITIAL PROBABILITIES	GP	TC	IF	MC	SC	MI
GP	0.43		0.11	0.14	0.14	0.16	0.17
TC	0.29	0.10		0.10	0.16	0.15	0.16
IF	0.20	0.07	0.04		0.12	0.11	0.10
MC	0.51	0.06	0.10	0.09		0.09	0.11
SC	0.45	0.12	0.09	0.11	0.14		0.14
MI	0.44	0.11	0.07	0.08	0.12	0.11	

III. THE DEVELOPED ALGORITHM

The Cross-impact method was based on the analysis of experts' opinions considered. The list of the 6 (six) events were considered relevant to the adoption of ICT in Basic Education. The events and their interpretations were as enumerated below:
The event1 represents Government policy
The event2 represents Teacher Competency
The event3 representsAvailability of ICT infrastructure
The event4 represents Integration of ICT in school curriculum by Ministry of Education
The event5 represents Student preparedness in adopting ICT in learning process
The event6 represents Perception of schools' management in adoption of ICT in schools
The initial probability $p(i)$of the separate event$e(i)$, was determined without considering how any other events might affect it, these were derived from the analysed experts' opinions. The conditional probabilities of the events taken in pairs were defined as follow:

$p(i/j)$= probability of event i given the occurrence of event j; and $p\left(\frac{i}{notj}\right)$ = Probability of event i given the non-occurrence of event j

Thus, the opinion given by the experts through the administered questionnaire were corrected in such a way that the final probabilities were in conformity with the following three elementary postulates of the calculus of probabilities:

(P1) Normalization. $0 \leq p \leq 1\ foranyprobabilityp$ (P2) Rule of the product.$p(i.j) = p(i).p\left(\frac{j}{i}\right) = p(j).p\left(\frac{i}{j}\right)$

(P3) Rule of addition. $p(iorj) = p(i) + p(j) - p(i.j)$

The conditional probabilities were calculated from the cumulative probability distribution equation:

$p\left(\frac{i}{j}\right) = \frac{p(i)-p(notj)*p\left(\frac{i}{notj}\right)}{p(j)}$, where

$p(i)$= probability that event i will occur (Initial probability of event i)

$p(j)$= probability that event j will occur (Initial probability of event j)

$p(i/j)$= probability of event i given the occurrence of event j (Conditional probability)

$p(j/i)$ = probability of event j given the occurrence of event I (Conditional probability)

$p(notj) = 1 - p(j)$ = probability that event j will not occur

$p(i/notj)$ = probability of event i given that j does not occur (non-occurrence)

The smallest possible value for $p(notj)$ is 0 (zero) and the largest possible value is 1(one) the range of the probability of event i given the occurrence of event j (conditional probability) is:

$$\frac{p(i)-p(notj)}{p(j)} \leq p\left(\frac{i}{j}\right) \leq \frac{p(i)}{p(j)}$$

Thus, the probabilities were checked in order to be sure that the estimated values fall between the acceptable limits. The Solved $p\left(\frac{i}{notj}\right)$provided the non-occurrence probability and answered the converse to the conditional probability question that if event j did not occur, what is the new probability of event i? The non-occurrence probability matrix was calculated once the conditional probabilities had been verified.

$$p\left(\frac{i}{notj}\right) = \frac{p(i)-p(j)*p\left(\frac{i}{j}\right)}{p(notj)}$$

The developed algorithm entails the following steps:

STEP 1: Start {by identifying the events [n] relevant to adoption of ICT in basic education}

STEP 2: Input n;

STEP 3: Input initProb[n];

STEP 4:

i. Input Matrix M1=Matrix[n,n];
ii. Input Matrix M2=Matrix[n,n];

STEP 5: Input i=0,j=0; initialise i and j to 0

STEP 6: Repeat {Compute odd ratio}

i. ComputeOddRatio1[i,j]=M1[i,j]/(1-M1[i,j]);
ii. Compute OddRatio2[i,j]=M2[i,j]/(1-M2[i,j]);
iii. Increment j;
iv. Until j=n;
v. Repeat
vi. Increment i;
vii. Goto i
viii. Until i=n;

STEP 7: Input i=0,j=0,; initialise i and j to 0

STEP 8: Repeat {Test for Occurence}

i. SET isCross=false; test for occurrence of i and j
ii. If i=j then
iii. SET isCross=true;
iv. If isCross=true then
v. Compute OccurenceoddRatio[i,j]=null
vi. Compute NonOccurenceoddRatio[i,j]=null
   else goto vii
vii. Compute OccurenceoddRatio[i,j]=M1[i,j]/([j,i])
viii. Compute NonOccoddRatio[i,j]=M2[i,j]/(1-M2[i,j])
ix. Increment j;
x. Until j=n;
xi. Repeat
xii. Increment i;
xiii. GOTO i.
xiv. Until i=n;

STEP 9: Select an event probability such that:

i. If rand> event
ii. Set IsOccur=false else
iii. Set IsOccur=true
STEP 10: Select
i. If IsOccur =true
ii. Compute J1= initprob[n]* M1[i,j] Else
Compute J2= initprob[n]* M2[i,j]
STEP 11: Repeat STEPS 3 to 10
Until Event[n]=tested
STEP 12: Repeat STEP 3 through 11
STEP 13: Compute freq=TotalNoOccurence/TotalNoRun
STEP 14: Set SelectedEvent=Event[n];
STEP 15: Input NewInitialProb=x
STEP 16: Repeat STEPS 9 to 15
STEP 17: Display NewMatrix[n,]
STEP 18: Stop

IV. CONCLUSIONS AND FUTURE WORK

In this paper, we have been able to develop an impact assessment algorithm for the adoption of Information and Communication Technology (ICT) in basic education using cross-impact method. For the establishment of the relevant events needed for the developed algorithm, this research work explored the creation and evaluation of a set of six major events that are responsible for the adoption of Information and Communication Technology in basic education in South-West Nigeria. The events are: Government policy (GP), Teacher competency(TC), Availability of ICT infrastructures(IF), Integration of ICT in school curriculum by ministry of education (MC), Student preparedness in adopting ICT in learning process (SC) and Perception of school's management in adopting ICT(MI). The developed impact assessment algorithm is characterized by the quantitative and qualitative methods of evaluating the adoption of ICT in basic education. It is sufficiently flexible to accommodate other impacts in future studies. It is recommended that future work should be geared towards implementation of the developed algorithm and qualitative evaluation of the same through analysis of variance, regression analysis and sensitivity testing.

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