Adaptive Learner-CBT with Secured Fault-Tolerant and Resumption Capability for Nigerian Universities

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Abstract—The post covid-19 studies have reported significant negative impact witnessed on global education and learning with the closure of schools' physical infrastructure from 2020 to 2022. Its effects today continues to ripple across the learning processes even with advances in e-learning or media literacy. The adoption and integration therein of e-learning on the Nigerian frontier is yet to be fully harnessed. From traditional to blended learning, and to virtual learning – Nigeria must rise, and develop new strategies to address issues with her educational theories as well as to bridge the gap and negative impact of the post covid-19 pandemic. This study implements a virtual learning framework that adequately fuses the alternative delivery asynchronous-learning with traditional synchronous learning for adoption in the Nigerian Educational System. Result showcases improved cognition in learners, engaged qualitative learning, and a learning scenario that ensures a power shift in the educational structure that will further equip learners to become knowledge producer, help teachers to emancipate students academically, in a framework that measures quality of engaged student's learning.

Keywords—*Adaptive blended learning; computer-based test; fault tolerant design; resumption capabilities; Nigeria; FUPRE*

I. INTRODUCTION

Learning is simply the process that leads to the alteration in the capability of a system causing a change in behaviour as it tries to accomplish tasks [1]. Learning thus, must yield a change or alteration in a system [2]–[4]; and thus, must equip and re-position the learner with a better knowledge to deal with task(s) at hand [5]. These changes may yield acquired skillsets, modified values, improved preferences and attitude, and new knowledge cum understanding for a learner [6]–[8] – all of which essentially improves a learner's experience and performance [9]–[11], and grants him/her the capability of new data readily, made available for future use in varying/similar instances of tasks [12]. Learning is a lifelong skillset acquired in a bid to accomplish a task over and over again [13], [14]. Learning modifies the behaviour of a learner system as it acquires the requisite skills and knowledge, which is therein stored and retrieved on demand access for use to

resolve challenges as well as assess risks, explore cum exploit challenges and opportunities [15], [16].

The covid-19 pandemic era witnessed a global lockdown of many public infrastructures with the following events namely: (a) closure of schools [17], (b) adoption of social distancing as a means to curb and reduce the spread [18], [19], (c) the migration and mobility pattern of residents from one place to another [20], and (d) adoption of nose-masks in public places [21], [22]. The post-covid-19 studies report that: (a) conventional schools were shut down to curb its widespread propagation, (b) enforcement of school shutdown resulted in various impact on the learning process for over 1.6 billion students, (c) short-term disruptions in the learning timeframe with significant negative impacts, and (d) these impacts rippled across the learning-verse, a variety of long-lasting effects in the formation of learner [23], [24].

The adoption of ICT has further bolstered and revolutionized the learning process with e-learning variants [25] as a means to help learners creatively contribute to knowledge creation (a hard feat to obtain in traditional schools with classroom settings). e-Learning today involves use of ICT-based services and electronic media-formats that can be replicated within medium that cuts across a variety of platforms in the learning process [26]. While, e-learning offers many benefits, the negative impacts of covid-19 era on education includes: (a) adoption of social distancing to curb the spread of the pandemic [27], (b) lessened migration of residents from one place to another, (c) adopting nose-masks in public places/gathering, and (d) closure of schools. Studies have reported that the covid-19-era – had significant negative-impact on the learning prospects of over 1.6 billion learners globally; and where such effects are not properly handled, may have long-lasting effects on the formation of such students.

The implications is: (a) non-access to physical infrastructure for learning, (b) yielded increased learning inequality and losses resulting from the stratified Internet access [28], [29], (c) learning disparities resulting from digital revolution/integration across a variety of learning platforms in

Nigeria (uLesson etc.), (d) the learner psychomotor and cognition health stability to adjust to blended, ICT-rich-learning paradigm as a new reality, and (e) learner adaptabilities to new complex logistics in these new paradigm, and other costs [30]–[32]. These, are determined through formative and summative testing.

II. METHODS AND MATERIALS

A. Computer-based Testing

Taking into account the changes already in place, there is a need to ensure that today's students are competent in science and technology. (Ojugo et al. [33] and Durojaye et al. [34]).The goals of science education must thus be: (a) to ensure basic science-tech literacy to enhance daily living of residents in our society today, (b) prepare learners for further training in science-tech, (c) develop skills and attitudes to prepare us for technological growth, (d) to improve learner creativity and innovation, (e) to enhance user-friendly interaction of various careers and provide knowledge applications. Fagbola et al. [35] Poor performance in science-tech can be attributed to: (1) the nature of the subject, (2) curriculum design, (3) teacher/learner characteristics, (4) the teaching style, and (5) disjointed teaching to meet examination deadlines.

To enable teachers and students harness unrestricted online access to resources in order to contribute and share knowledge with the rest of society, it is necessary to change these attitudes regarding education alongside summative testing based on CBT [36]. Technology integration with CBT is not the only thing that's going to get you into a knowledge era; rather, it leans more on the attitude of both the teacher/learner, and the requisite changes made via a paradigm shift by the teaching method as enabled by ICT. It is necessary for teachers to take on the basic issues, as well as questions about this and other topics such as:.(a) teacher's literacy and awareness in mixed learning;.(b) how teachers navigate a new technology together with their expectations around CBT [37].

B. Testing and Attitudinal Types

In order to enhance students' mastery of essential content, the pedagogical test is a way in which teachers use as part of their preparation for teaching feedback on continuing education and training. This also covers a wide range of formal and informal assessment methods and procedures used by teachers during the learning process in order to change the whole teaching and learning process through participatory learning, which are intended to improve learning results and retention of skills acquired throughout education [38]. Qualitative feedback for students/teachers that focuses on the content and performance is also involved, in addition to scores. Employed as assessment method, its practice presents students with clear learning targets, examples and models of strong and weak projects, regular descriptive feedbacks, the ability for self-assessment and track learning as well as set goals [39], [40].

Conversely, periodic quizzes, end-of-unit summative test, end-of-course tests and standard tests – all provide an overview of student performance at this point in time. They shall be used to assess the programme's content [41] in a formative manner and to grade it. Albazar [42] mentionsthe seven-principles of formative test as: (a) clarifies what good performance is about with set goals, criteria and expected standards, (b) it facilitates the development of self-assessment in learning, (c) provides quality content and engaged learnings, (d) encourages teachers and activates peer-dialogue around learning, (e) encourages positive motivational beliefs and self-esteem, (f) offers opportunities for bridging the gap between existing and desired performance, and (g) collects data for teachers that can be used as a tool for designing education and training [43], [44].

An attitude type refers to the expression of a favorable or unfavorable opinion about an individual, place, thing or event. The person's view of the target and how to talk or do things may also be referred to an attitudinal type [45], [46]. When we think about a person or something, it also means the feeling, attitude, position etc. It's a tendency or orientation in particular for the mind toward certain things [47], [48]. It refers, to the quadratic equation, to the attitude of students and teachers towards mathematics and science and technology education [49]–[51].

Iskandarov [52] Test is a *short* exam, which is grouped into formative and summative. The end of a course test is summative; while, the periodic test taken in an ongoing course is formative. To fulfil these two purposes, approximation tests are carried out to obtain a number of data on the programme's effects as well as diagnostic data for its deficiencies [53]. The Nigerian Teacher Institute groups testing into assessment methods as thus: (a) out-of-class, (b) open-book and (c) closed-book. These impact the attitude of the learner as it pre-disposes a learner to respond in a certain way. Younis et al. [54] attitude encompasses a range of affective behaviour with cognitive, psychomotor dimension that is measured via a self-report instrument. Attitude is a powerful motive in realization of a learner's expected goal(s).

C. Study Motivation

These challenges include (and not limited to) [55]–[57]:

1) Paradigm shift: The covid-19 era caught many societies, completely unprepared with the adoption/adaptation of ICT into education with Nigeria as case in point. With this shift and reform, parents and teachers had to switch their roles to become facilitators (that they were unprepared for).

2) Questions framework: The stratification of Internet access portends and presents network administrator(s) of the system that new questions must be uploaded onto the ensemble from time to time – to increase the pool of questions from which test-questions are drawn. Since the process is accomplished via scripting – a measure of error is unavoidably introduced with the addition of more contents onto the CBT platform.

3) Resumption feat: Most CBTs in administering questions – are pooled from their offline repository which are often clocked. A major issue in adopting e-learning with CBT capability is the lack of resumption ability with the learning management system (LMS) especially in lieu of physical infrastructure downtime, power outage and network failure.

4) Poor integrity delivery outcome on the learning setting: The impact of the covid-19 era birthed the sudden need to adapt online teaching/learning [58], and also challenged the readiness of schools on paradigm shift to digital revolution readiness [59]. This forced adoption/adaptation of blended learning (i.e. e-learning that combines both a(synchronous) learning settings). These learning settings differed in terms of time, and the place of teaching/learning activities [60]. However, some of the challenges in the learning setting has been found to include: anonymity and social presence gaps, learning modalities, lower satisfaction, technophobia, lower cognitive achievement, disengaged participation in class of learners, fluency and slower interaction resulting from videoconferencing in e-learning [61]–[63].

D. Proposed Adaptive Architecture for the Learner-centric Computer-based Testing (AdACoBaTe)

Fig. 1 leverages on Dominic and Francis [26] model for e-learning as extended by [64] – which then provisions a test-based framework, which classifies learners into test groups, and proposed corresponding methods using the Sarasin model based on their learning styles namely: (a) visual learners who gain new facts and knowledge via visual inputs, (b) auditory learners who learn by listening to a teacher or teaching medium, and (c) kinesthetic/tactile learners learn via experiments and exploration (using Montessori means); however, both Hidayat and Utomo [65] commented that when a teacher is aware of the three types of learning styles outlined in Felder Silverman's 32-variant classroom activities they become more sensitive to designing exercises for improving teaching learning processes.
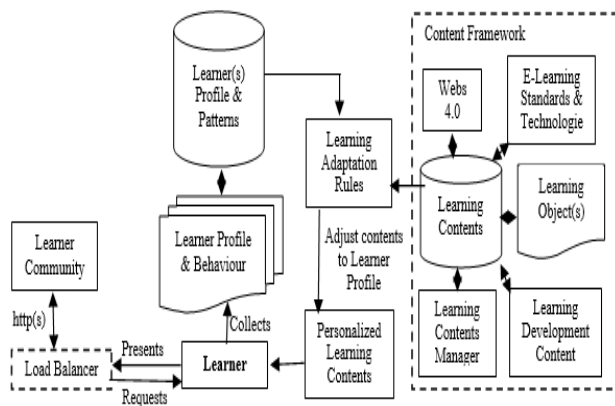
formed patterns and adapted rules., and (d) it responds to learners with personalized learning contents provided by the adaptation model [66], [67].

2) The Adaption Component is the main processor for the experimental adaptive e-learning system. It performs these tasks: (a) it stores all learners profiles and their learning patterns into a repository, (b) it simplifies task(s) by responding to each learner, (c) it captures the browsing history, pattern and behavior of learners, and updates the captured data in its knowledge-base – helping the model to keep up with each learner and to transition between the learner profiles, (d) it uses its data content repository (or knowledge-base) about the learner's profile to adjust the adaptation rules (and module) for each learner; And thus, identifies best learning style, learning path and learning contents suited for each identified learner, (e) it builds the personalized learning contents and hands them off to the learners' model to present to a learner, and (f) it retrieves all contents required from the content model [68].

3) Personalized Learning/Test-based Content retrieves the learner's profile and (a) provide adaptive contents from model, (b) retrieve the personalized learner's questions in lieu of learned contents, and (c) stores them as temporary session to ease access to the contents and ensure that as the knowledge-base grows, performance is not degraded with the increase in users and the system shift between profiles [32]. Fig. 2 and 3 – show the state diagram of the ensemble as each learner log-in onto the CBT-system with resumption capabilities and fault tolerant design [69].
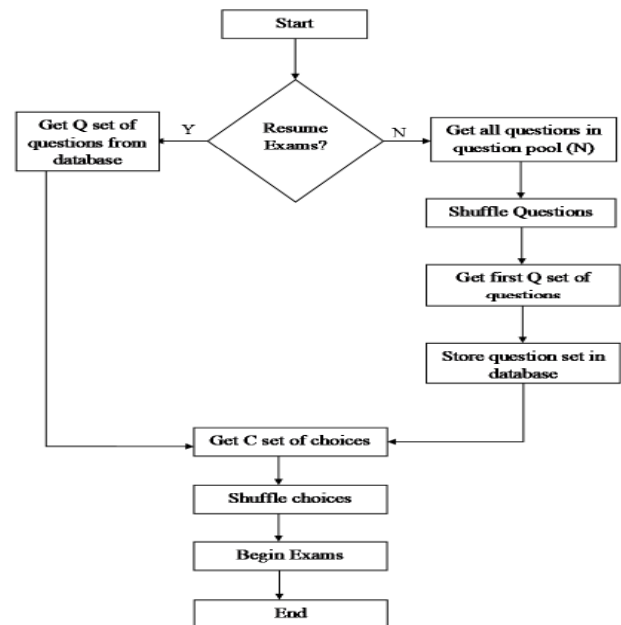

Fig. 1. AdaCoBaTe: proposed adaptive content-based testing with resumption capabilities.

The workings of the ensemble is thus:

1) The Learner Profiling Component is that which directly interacts with the learner. It performs these tasks as thus: (a) all request and response are via HTTP/HTTPS format, (b) all request from the learning process is transmitted to a load balancing server that balances traffic on the basis of planned data structure and algorithm, (c) it collects data about learners profile and their learning behaviors, then sends them on to an adaptation model stored in a repository where they can be

Fig. 2. Algorithm for randomized adaptive learner-based content with resumption capabilities for AdaCoBaTe.

4) The Content Component – *performs these tasks:* (a) acts a repository for all the learning objects developed by a tutor cum administrator – allowing them to add/delete

questions to the pool, add/delete students list to an exam as well as monitor and manage the examination process, (b) ensures that a learner-content is based on the learning styles ratio as agreed in [70] and as suggested (i.e. visual 40%, kinesthetic 40%, and audio 20%, (c) develop contents using the latest web-tech (i.e. web 4.0 used to generate learner contents), and (d) use learning content development, management tools, and learning standards [71], [72] to proffer a system that is compatible, portable, can be ported to other systems of varying operating systems, shareable and interoperable with other e-learning systems. The preferred learning content ranges is as thus: (a) visual learning style consists of lecture materials, video lessons, animations etc, (b) kinesthetic consist of simulations, online quizzes, discussion forum, online compilations and question banks etc, and (c) audio consists of audio materials and accounts for 20-percent of learning styles.
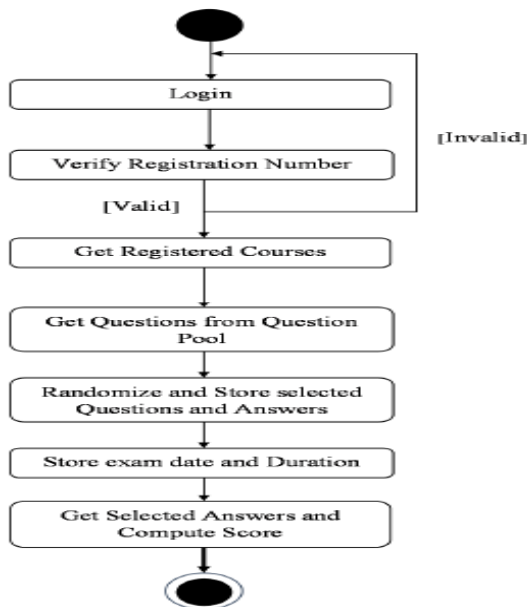

Fig. 3. Learner login with CBT access on AdaCoBaTe.

In order to prevent cheating and negligence on the part of students, a randomised question set is generally given for each student in an examination. System interfaces are easy for new computer users to use as they can navigate on a keyboard with their own set of keys. The proposed system is tolerant of failures because if there are incidents of network disruption, component failure or power outage during a test, the student's progress can be quickly restored.

a) Fault tolerance: Prior to the point of power-, component- and network-failure, system shall be capable of recover from a fault and resume the examination. Faults that occur during exams are recovered by the system. A student will not re-start the entire exam in such a case. System achieves this by tracking the entire exam, and allowing the user to resume an examination prior to the point of failure.

b) Power failure: The ensemble during examination shall be able to store each selected selection made by the student in in its database and a copy will also be retained for temporary session storage. The CBT tracks client system IP-address during exams. With power fault, a user will be disconnected for an extended period pending the restore of power. If the IP address is not changed, student can re-log in and continue on the same system soon as power is restored to the machine. Also, prior to power failure, the client agent will initiate a countdown from the remainder time saved in the database. Ensemble retrieves the queries that have been entered in the database and divides them into various sets of questions, options or chosen answers.

c) Network fault: With a network fault, the client agent must not be able to send a student's newly selected answer to the orchestra if his or her computer has been disabled for an exam. To restore the network, system operation will be interrupted on the client side. The ensembles are keeping an eye on that idle time during the exam. The ensemble will give a student reallocation of idle time if it is beyond the 500-seconds threshold. Once network is back up, students are allowed to continue with their examinations from where they were before a technical failure occurred.

III. RESULTS AND DISCUSSION

A. Ensemble Performance Evaluation

Divayana [70] design seeks to ensure in e-learning systems such as public ethics, quality, accountability, nationalism etc. He categorized these feats into 10-dimensions as supported by Ojugo et al. [73]. We recast interaction with the system as a 9-dimension feat: (1) design effectiveness, (2) availability of video conference, (3) CBT readiness, (4) technical support, (5) teacher/learner use of system, (6) availability time, (7) the availability of resources, (8) the completeness of resources, and (9) data security. He used Eq. (1) to analyse the effectiveness of the learning style(s) and categorized into 4-percentiles: (a) high ranges from 81-100%, (b) sufficient from 61-80%, (c) moderate from 50-60%, and (d) poor falls below 50%.

Both categories high and sufficient – implies the learning design does not require any revision. Moderate requires some form of revision; while, the category poor implies a complete revision of the learning design. Thus, evaluation for both experts and participants yields the Table I and II respectively.

$$EP = [F/N] * 100 \qquad (1)$$

Table I shows high and sufficient category ranging above 85% for all the evaluated variables by the various experts. The implication of which, is that these components do not require revisions of any kind. However, the data security component can be improved upon and agrees with [74].

TABLE I.   EXPERTS' EVALUATION ON LEARNING / CBT DESIGN

Features	Experts' Evaluation Scores				
	1	2	3	4	5
Design Effectiveness	0.89	0.96	0.91	0.89	0.92
Availability of Video Conference	0.91	0.87	0.91	0.94	0.89
CBT Integration	0.75	0.89	0.79	0.89	0.91
Technical Support	0.85	0.90	0.92	0.88	0.91
Effective Usage of Framework by Teacher/Learner	0.92	0.92	0.86	0.85	0.90
Duration & Resumption Capacity	0.91	0.90	0.93	0.98	0.89
Reliability of contents	0.89	0.89	0.78	0.69	0.93
Completeness of resources	0.79	0.91	0.87	0.91	0.96
Data Security	0.76	0.67	0.88	0.95	0.89

TABLE II.   PARTICIPANTS' EVALUATION ON LEARNING / CBT DESIGN

Features	Participants' Scores		
	σ	µ	+Di
Design Effectiveness	0.27	0.94	0.89
Availability of Video Conference	0.27	0.87	0.89
CBT Integration	0.23	0.82	0.73
Technical Support	0.33	0.90	0.95
Effectives Use by Teacher/Learner	0.28	0.81	0.78
Duration and Reciprocity	0.38	0.81	0.72
Reliability of contents	0.31	0.80	0.86
Completeness of resources	0.29	0.93	0.76
Data Security	0.13	0.85	0.72

Table II shows participant evaluation with mean, standard deviation and dyadic interaction between participants and the system. It yields a mean effectiveness in the ensemble use with over 90%, and a dyadic interaction that is above 70%. Also the relationship on the interaction between the participants and the e-learning platform cum system is sufficient.

B. Result Findings

The resulting resumption capability allows student's time to be recovered soon as fault is rectified. The system records the last activity during connectivity loss, and restores the time spent on it. If loss exceeds a threshold of 500 seconds, time is restored only if it persists. Ensemble resumes activities via automatic retrieval of remainder time, question-set and selected choices as in Fig. 2. The IP address and hostname of the client system, assigned to the user's registration number during the exam, shall also be used to restart the learner's session from the same device if and when the power is lost. This agrees with [75], [76].

Furthermore, the complexity with which examinations are scheduled is eliminated by using a series of simultaneous tests. The database is filled with a list of registered courses for each student. A student is entitled to write any scheduled course(s) registered, once the course schedule has been set. An algorithm for random selection of questions, is implemented

to avoid the same sequence of questions and answers being assigned to students. Eq. (2) is used to validate the algorithm so that the probability a student gets the same sequence of questions with the same sequence of choices is denoted by P(R):

$$P(R) = \frac{Q*S}{N*Q!* \pi_1^Q C_i!} \qquad (2)$$

Where Q is the number of exam's question is Q, C_i is the number of choices for Q_i (where $i=1...Q$), the number of students is S, and the total number of questions stored in the database for this exam is N (where $Q<=N$).

C. Discussion of Findings

We model the AdaCoBaTe ensemble to resolve the issues of fault-tolerance and resumption capability to reduce the effect of the occurrence of faults that may occur from power, network and physical infrastructure failure(s) – that may disrupt or terminate an examination. This can result in timing out that will eventually supposedly log out a user. To restore lost time, the system would monitor client computer connectivity to a server in order to solve this problem. System will restore the clock to when a student has last been in touch with this server if connectivity is lost for more than 500 seconds. In addition to restoring the rest of the period, if an exam is restarted, question set and selected choices are restored. This agrees with [77]–[79].

The algorithm for random selection of questions, its random distribution and random choice of responses – were developed and used. In general, it reduced examination malpractice as is corroborated by Fig. 2. A database is kept of the randomized question sets and selected answers, which are assigned to students when examinations resume. The random algorithm uses inbuilt-PHP shuffle function to ensure that sets of randomly selected questions are distributed normally. A comparison of the features of the proposed system to some popular online testing systems has been carried out. Automated resumption of tests will facilitate the adoption of Web based examinations by institutions that do not require uninterrupted power or Internet connection. This agrees with [80]–[82].

Further research can be poised toward the application of this study to online exams with descriptive questions, and not just multi-choice questions, and seek new means to track all assigned questions (alongside the selected choices as database size grows larger and for larger examinations). Also, to advance its security also, further studies can propose live image capture for students undertaking the exams as a means to detect impersonation when the exam is strictly online/web-enabled.

IV.   CONCLUSION

To reposition education as a key integral facet of the society as recovery strategies against the impacts of covid-19 pandemic – requires strong policies, which will yield unexpected high-end results. And though, the impact in Nigeria (on a grander-scale) was not as projected – the shocks and disruptions as experienced with covid-19, still raises important educational concerns that only new reforms can

answer and help with national recovery. The questions raised as reflection of the local realities vis-à-vis implementation of platforms to exchange experiences will in turn, foster effective strategies cum policies to help repair the wreckage impacted on the society by covid-19 – and mitigate future pandemic. This CBT ensemble can be implemented on a Campus-Intranet design to help curb the issues of privileged control as well as security risks that comes with its access via the Internet. This intranet-based design mode will also curb the issues of interoperability. The personalized delivery outcome on the e-learning setting seeks to minimize the effects of anonymity and social presence gaps, advances an improved learner satisfaction with the tailored content delivery, improved cognition, and better engaged participation in class of learners.

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