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Development and Utilisation of Physics Learning Management System for Learning Difficult Concepts in Senior Secondary School Physics – Methodological Insights

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Abstract

While science educators were battling the challenge of difficulty in learning physics, the sudden outbreak of the COVID-19 pandemic and the consequent lockdown of schools, compounded the existing ugly situation. This paper explored the methodological insights to the development and usability of Physics Learning Management System (PLMS). The study adopted the type II developmental research design to develop a functional PLMS using some of the existing digital technologies. Multistage sampling procedure was adopted to select 27 secondary school physics teachers in the six south-western states of Nigeria. The selected teachers were trained on the rubrics of instructional video production, Learning Management System and Culturo-Techno Contextual Approach (CTCA) model to teaching physics for five weeks. The results obtained were 86 instructional videos on perceived difficult topics in physics which were used as the content of the PLMS. To establish the validity and usability of the PLMS, 298 physics students were randomly selected from six public secondary schools across six states in south-west Nigeria. Feedback from the students and other technical observations were used to improve the functionality and usability of the PLMS. We hypothesized that the outcome of this study will over time, in addition to other similar initiatives, enhance physics learning in Nigeria in response to the call of the new normal and 4th industrial revolution. In addition to the urgent call for facility upgrades in public schools to promote virtual learning, it is also recommended upskilling and further capacity building should be encouraged among science teachers.

Keywords: *Instructional Video, Learning Management System, Culturo-Techno Contextual Approach, Physics Pedagogy*

INTRODUCTION

The curriculum document of 1985, which was revised in 1998 and 2011 (FME, 2011) emphasized the centrality of physics education at the secondary school as a tool for igniting scientific and technological consciousness among scientifically conscious young Nigerians (Amusa 2021). Unarguably, physics education is an inevitable tool to navigate the pathway into the fourth industrial revolution. It is an instrument per excellence to activate technological advancement, promote innovativeness, improve healthcare and accelerate industrialization (Bello & Akinfesola, 2015; LeeRoy, 2012). The objective of studying physics, according to Mansfield & O'sullivan (2020) is to investigate all aspect of material world in an attempt to discover the fundamental laws of nature and hence to understand and explain the full range of phenomena in the physical universe. The significance and relevance of physics as a subject at the secondary school level is not in doubt. Its concepts and techniques underpin the progress of all other branches of science (Usman, et. al., 2019). Unfortunately, the subject does not seem to attract the young ones as expected, nor are the students taking the subject performing to expectations. Many of the students perceived the subject as very abstract and very difficult to learn (Owolabi, 2020).

Before the pandemic, research efforts have identified two potent factors that contribute significantly to the recurring poor performance of the students in both internal and external examinations (Amusa, 2019). A huge deficit of trained and competent physics teachers, and the teachers' choice of teaching method (Adewusi, 2020; Oyenwuchi, 2020). The long-standing problem of insufficient professionally trained and certified physics teachers has remained unresolved. This problem coupled with the use of teaching strategies that do not conform with the context of the learners, has led to the persistent boredom experienced in physics class, poor perception of the subject and unsatisfactory achievement of senior secondary school students. This poor beginning often culminates into poor achievement in physics, creates a lack of interest among the students, and ultimately prevents them from pursuing physics as a future career and other science and technology-related courses.

While science educators were deeply engrossed in search of enduring solutions to the array of challenges bedeviling the teaching and learning of physics at the secondary school level, the unfortunate outbreak of the COVID-19 pandemic with the consequent lockdown and movement restriction further compounded the challenges of physics learning (Amusa, 2020b;). UNESCO (2020) and Hollweck and Doucet (2020) noted that school closure occasioned by the COVID-19 pandemic affected over 1.55 billion students while 1.6 million teachers were physically cut-off from their learners. This led to a paradigm shift in instructional delivery strategy (Onyema, et. al., 2020). Just as the world was trying to recover from the huge social and economic downturn, the surge of other variants such as Delta and Omicron were announced in 2020 and 2021 respectively (Amusa, 2021). There was a reported case of sporadic outbreak of same virus in the 2022. But it was subtly announced in China. This indicates that the storm is yet to settle.

As bad as the COVID-19 incident sounds, the unpalatable experiences served as an eye-opener to educators on what possible remediation and innovative approaches can be adopted to improve the current state of physics learning in Nigeria secondary schools and other institution of learning (Onyema, et. al., 2020). While the countries of the western world and Asia were able to maneuver the lockdown to continue their education through the online mode, most of the countries in Africa were not so lucky due to poor infrastructure and inadequate online resources (Adedoyin, & Soykan, 2020). Even though, no country ever prayed for the replay of what occurred during the COVID-19 crisis, it becomes imperative and logical to make provision for "war at the time of peace". Physics educators are therefore, actively involved in the preparation of virtual learning resources at all levels of learning. One of such efforts was the study carried on the development of physics learning management system for senior secondary school students in Nigeria and sub-Saharan Africa using the Culturo-contextual approach (CCTA) to teaching sciences (Okebukola, 2020; Oladejo et al., 2021). Simultaneously, this effort also aimed at addressing the challenges of insufficient professionally trained, certified, qualified and competent physics teachers that pervades the learning space in Nigeria schools.

Given the available information in the literature and toeing the direction of what works, it was hypothesised that adopting of culturally relevant and contextually sensitive teaching approach will help to improve the delivery of physics instructions. Such approach which depicts physics as a unit of knowledge within the culture of the students, respects their worldviews and relates classrooms instructions to their everyday life has been established in the literature as potent in enhancing students' performance and sharpening their critical
consciousness to reason deeply and well enough to challenge exiting statuesque logically (Abah et al., 2014; Gbamanja, 2014; Bryd, 2016; Glover & Williams, 2017; Ladson-Billings 1995; Okebukola et al., 2016; Egerue, 2019; Adam, 2020; Oladejo et al., 2021; Gbeleyi et al., 2022; Onowugbeda et al. 2022). On the other hand, we recognized that the challenge of insufficient qualified physics teachers will not be resolved overnight, and meaningful learning of physics is unnegotiable for national development in science and technology, hence we resolved that an enhanced version of what we did during the lockdown should be a viable alternative, that is, use technology to disseminate information and deliver learning to the door step of the physics students. Therefore, the study developed a Physics Learning Management System (PLMS) and deployed the platform for the use of senior secondary school physics students within the six states in south-west Nigeria.

LITERATURE REVIEW

This study is premised on the cognitive theory of multimedia learning as postulated by Mayer (2021) and (2005) which posited that cognitive theory of multimedia learning is based upon three postulations that are premised on cognitive science principle of learning with the following assumptions:

1. Human information processing system include two channels for visual/pictorial and auditory/verbal processing
2. Each of the channel possess a limited capabilities for processing information
3. For learning to be active, it must be carried out with a set of cognitive tasks which include filtering, selecting, organising, and integrating information
   This framework demonstrates how multimedia materials are processed step-by-step, moving from external representations to internal cognitive processing, with prior knowledge playing a critical role in understanding and retention.

The five cognitive processes identified by Mayer (2005) as outlined in Table 1 focused mainly on the correct selection of words and images. Appropriate selection of words and images in the production of multimedia messages are very critical in this multimedia learning. To enable learners, generate the right sound and expected mental picture in their working memory, the teacher or instructional designer must select the most appropriate words and images. Furthermore, the organization of these words and images are also essential to enable learners establish coherent connection between words and images.

Table 1 Five Cognitive Processes in the Cognitive Theory of Multimedia Learning

Process	Description
Selecting words	The learner focuses on specific words in a multimedia message to generate sounds in their working memory.
Selecting Images	The learner focuses on relevant images in a multimedia message to form mental pictures in working memory
Organizing words	The learner establishes connections between chosen words to form a coherent verbal model in their working memory
Organizing images	The learner forms connections between chosen images to develop a cohesive mental picture in working memory
Integrating	Learner builds connections between verbal and pictorial models and with prior knowledge

Table 2 further outlines the five forms of representation in the Cognitive Theory of Multimedia Learning. Mayer (2005, 2021) illustrated how different types of information are processed and stored in the human cognitive system during multimedia learning. He posited that words and pictures (Multimedia Presentation) refer to the presentation of information in multimedia formats which typically involves a combination of text (words) and visuals (pictures). These are external representations that are provided to the learner during the instructional process. This occurs at the level of multimedia presentation, which is the initial interface between the instructional material and the learner. Meanwhile, acoustic and iconic (Sensory Memory Representations) describes the situation when learners perceive multimedia materials and the sensory memory registers information in its raw form — acoustic representations for sounds and iconic representations for visual elements. These raw sensory inputs are held briefly in sensory memory, which acts as a temporary holding space. Similarly, for sounds and images (Working Memory), once processed from sensory memory, the sounds and images are transferred to working memory, where learners actively process and interpret them. This is where auditory and visual elements are aligned and understood (Mayer & Moreno, 2010). In working memory, learners begin to manipulate and combine these elements to construct meaning.

Table 2 Five forms of Representation in the Cognitive Theory of Multimedia Learning

Type of knowledge	Location
Words and pictures	Multimedia presentation
Acoustic and iconic	Sensory memory representations
Sounds and images	Working memory
Verbal and pictorial	Working memory
Prior knowledge	Long-term memory

Verbal and Pictorial (Working Memory) - In working memory, verbal representations (words, either read or heard) and pictorial representations (images) are integrated. This integration helps learners form coherent mental models. These representations exist simultaneously in working memory, emphasizing the role of dual-channel processing (visual and auditory). For prior knowledge (Long-Term Memory), learners relate the new information to prior knowledge stored in their long-term memory, which allows for deeper understanding and retention. This step is crucial for meaningful learning and knowledge construction. The long-term memory acts as the repository of previously learned information and serves as a resource for linking new content to existing schemas (Chang, *et. al.*, 2010).

The assumptions underlying this theory are consistent with the operational principles and resources provided by any Learning Management System (LMS). The audio-visual materials integrated into the LMS adhere to the dual-channel assumption of information processing. The visual/pictorial elements are delivered through the computer interface; for instance, in an electrolysis experiment demonstrated via video instruction, students can observe and conceptualize the movement of electrons from the more reactive to the less reactive electrode, as well as the function of the salt bridge in balancing the excess ions at each pole. This process goes beyond the mere presentation of images; it facilitates the construction of a mental representation in the learner's working memory, enhancing cognitive engagement with the material.

In accordance with Mayer and Moreo (2003), the auditory or verbal component pertains to the teacher's explanation or background discussion, which is integrated into a series of lesson videos. Recognising the limited capacity of cognitive channels, the information presented to students is divided into manageable segments and carefully sequenced, ensuring that no lesson video exceeds 20 minutes in length. Furthermore, the active learning assumption is evidenced by the learner's ability to transfer acquired knowledge to analogous real-world situations. While the learning environment is virtual, the knowledge gained is expected to have tangible applications. This theoretical framework underpins the proposed study, advocating for the use of Learning Management System (LMS) resources as a multimedia tool that fosters meaningful learning outcomes.

Okebukola et al. (2020) highlights some of the topics in senior secondary school physics that students perceived to be difficult. Prominent among these topics include concepts like refractive indices, electromagnetism, radioactivity, physics in technology, and motion without materials. Simpler topics, such as gas laws and Newton's laws of motion, were perceived as less difficult. The studies also reveal socio-economic disparities in educational resources, with privately-owned schools effectively using Learning Management Systems (LMS) during the COVID-19 pandemic, while government schools struggled due to limited access to infrastructure and capacity. Amusa (2021) emphasizes the need for government intervention to bridge this gap and ensure equal learning opportunities. Unarguably, eLearning has its limitation and challenges, as Hullon, Tucker and Green (2020) observed. It however remains the most viable alternative to face-to-face teaching. Although, the COVID-19 crisis seems over, all schools have returned to the usual face-to-face teaching and learning mode with little or no usage of the virtual platform. This portends another danger to the future of learning. Preparation for another unexpected eventuality similar to that of COVID-19 pandemic must be implemented. However, it is appropriate to act now and salvage the future of all learners, particularly the secondary school physics students who may not have access to any robust LMS for learning physics. Research efforts in the area of design, development and utilisation of LMS must be scaled up.

The Learning Management System (LMS) Is a software tool that provides a range of services that assist teachers with managing their courses (Ellis, 2009). It provides a platform for offering pedagogical content, creation of personalized paths for training, tools for communication and collaboration and student management activities. The LMS provides a hybridization of four learning theories, namely the traditional pedagogy, behaviourism, cognitivism and social constructivism (Ouadoud et al, 2017). The principle of operation requires the learner/student to consult and download the multimedia and textual resources placed by the teacher who is responsible for creating and managing the educational content on the platform. The teacher further provides engagement by monitoring activities and providing opportunities and tools for communication and collaboration. Technical administrations are also involved in the process by providing customizations, installations, maintenance and access management.

This study is pivoted on Nutley et. al. (2002) diffusion-adoption framework. This framework shows how evidence and ideas from a diverse range of underpinning disciplines are drawn together to arrive at a plausible decision or innovation and its subsequent adoption. The stages and interconnected of the variables are as shown in figure 1. The adoption process according to Roger (1995) begins with an individual or group moving from a state of ignorance (pre-contemplation). In this case, identification of problem (developing a learning management system to circumvent the rampaging effect of COVID-19 on the smooth running of the school system). This leads to the state of conscious awareness wherein evidence and ideas from a wide range of underpinning disciplines are drawn together in order to provide a range of perspectives on the development of an innovation (Physics Learning Management System).

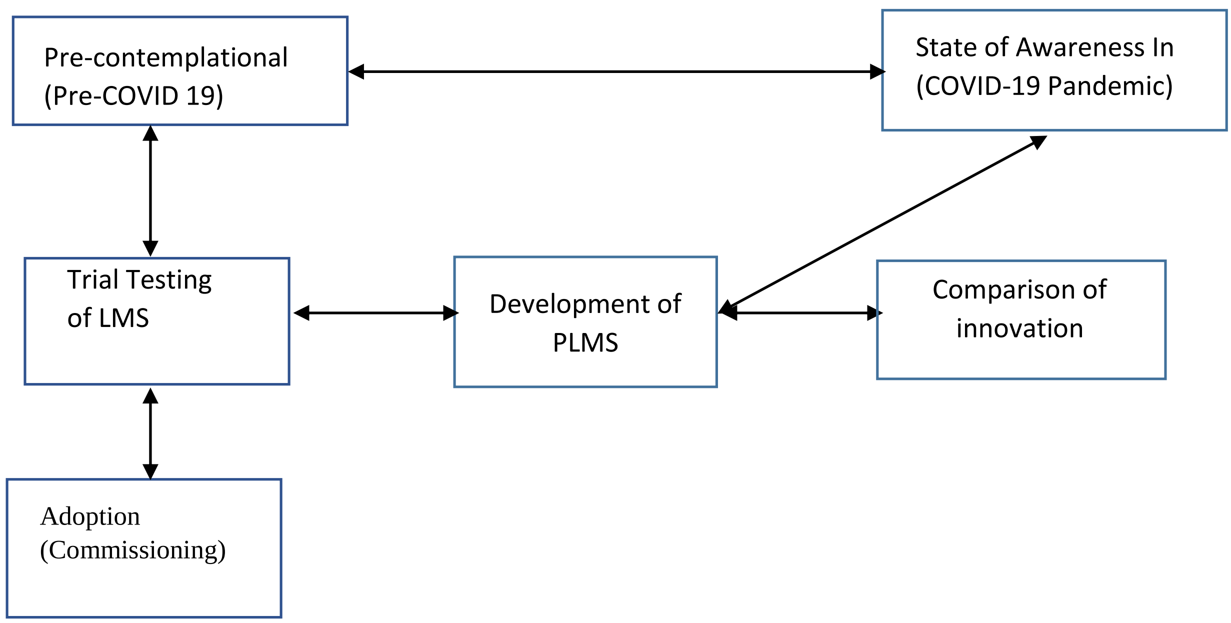

Figure 1 Diffusion-Adoption Framework as Applied to this Research Work

The pLMS is developed from this concerted effort. The pLMS is trial tested and compared with the situation at hand to determine its efficacy. This is the stage of experimentation in the study. If the innovation is desirable, sensitization of end-users, capacity building of physics teachers and other personnel relevant to the study are carried out. Any feedbacks are injected into the development of the innovation until a satisfactory outcome is achieved. Then comes adoption and subsequent diffusion of innovation. Otherwise, the research effort is re-enacted from the pre-contemplation state with the aim of diagnosing the predicament(s) and the cycle is repeated until a satisfactory outcome is achieved.

Given that through modern technology, it is possible for one competent physics teacher to actively teach hundreds of students across several geographical divides synchronously or asynchronously. We conjectured that if physics contents can be made available for secondary school students across the South-West states without any barrier or restriction in time and space, the problem of poor performance in physics due to insufficient teachers would have been half-solved.

The purpose of this study is to develop a functional Learning Management System for teaching and learning secondary school physics that will conform with the current realities. Other specific objectives are to

provide a functional platform for continuous learning of secondary school physics at any place and time, provide access to a simplified physics instruction with specific attention to perceived difficult topics in senior secondary school physics, and provide intensive capacity building to selected physics teachers on the use of LMS

METHODOLOGY

In this study, we adopted the Type II Developmental Research Design, as categorized by Richey and Klein (2005). This design focuses on the systematic creation and evaluation of educational interventions in real-world settings. Specifically, our approach aligns with the Instructional Design and Development Model, which emphasizes iterative development and empirical validation of instructional materials to address identified educational needs. To ensure methodological rigor, our developmental research process was structured into four key stages: preliminary need analysis, design, development, and evaluation.

Preliminary Need Analysis

The preliminary need analysis stage was conducted in collaboration with the state ministries of education across the six states in Southwest Nigeria. Through surveys and focus group discussions, we identified significant gaps in physics instruction, including inadequate use of technology and a lack of proficiency in creating engaging instructional materials. Prior to the commencement of the study, a need assessment survey involving 120 physics teachers in south-western part of Nigeria was conducted to determine their level of familiarity with the production and use of instructional videos as shown in Table 3. It was revealed that 92.6% representing 109 out of 118 respondents were not familiar with script writing and story boarding which are fundamental to instructional video production. Meanwhile, 7.4% of the teachers claimed moderate level knowledge of the two skills. While 56.8% of the teachers, representing 67 out of 118 respondents, agreed to their poor knowledge on the use of PowerPoint, 11.0% expressed their advanced skill in the creation of excellent slides for instructional video production. On the whole, 89.5% of the physics teachers believed that the required knowledge-base for instructional video production is non-existent while the remaining 10.5% of the physics teachers believed in their moderate knowledge on the skill. While 11.9% of the physics teachers laid claim to their online presence on YouTube through their instructional videos, the larger percentage of 88.1, representing 104 out of 118 respondents do not have online visibility to support their physics class. These results established a clear need for targeted capacity-building interventions on script writing, storyboarding, instructional video recording, creation and uploading of videos to YouTube channels and utilisation of such videos for instructional purposes. The need for the adoption of local contents in instructional video production was also identified. Hence, the training on Culturo-Techno-Contextual Approach (CTCA) to teaching was also emphasized.

Table 3 Descriptive Analysis on Physics Teachers Familiarity with Instructional Video

Components of Instructional Video/Frequency	Script Writing	Storyboarding	PowerPoint Skill	Instr. Video Skill	Instr. Video on YouTube
None	92.6% (109)	92.6% (109)	56.8% (67)	89.5% (106)	88.1% (104)
Moderate	7.4 % (9)	7.4 % (9)	32.2% (38)	10.5% (12)	N/A
Advanced	0%	0%	11.0% (13)	0%	N/A
Available	N/A	N/A	N/A	N/A	11.9% (14)

Design Stage

In the design stage, we developed a comprehensive rubric to guide participant selection and training module development. The selection criteria required teachers to hold a minimum qualification of BSc. (Ed.) Physics or equivalent, have a minimum five years of teaching experience, possess a functional internet-enabled laptop and demonstrate proficiency in Microsoft Office. In addition, the selected physics teachers had least ten years of service remaining with their respective state government. This is to ensure sufficient time in the transfer of knowledge acquired to other academic members. The training modules were meticulously designed to enhance participants' Technological Pedagogical Content Knowledge (TPACK) and practical skills in instructional video production and online teaching.

Development Stage

The development stage involved a two-tier participant selection process. First, ten physics teachers were nominated by each state ministry based on the selection rubrics shown in Table 4. This resulted into a pool of 60 teachers from the six south-western states of Nigeria. These selected teachers participated in virtual screening session with a six-member panel of physics education experts, during which their technological pedagogical content knowledge (TPACK) was assessed. From this process, 40 teachers were selected for the six-week capacity-building. Details of the virtual training are contained in Appendix 1 and Appendix 2.

According to the schedule in Appendix 1, day 1 to 10 featured discussion on basics of instructional video, stages in video production, script writing, storyboarding, creating instructional video with PowerPoint and other media, uploading of video to YouTube and embedding the link on course page, and Culturo-Techno-Contextual Approach to teaching physics. Two days were assigned for review and feedback on practical task. The schedule in Appendix 1 also highlights the roles of the facilitators and participants accordingly. As a follow up to the training, participants engaged in practical tasks, such as development of physics contents on the assigned physics topics, script writing, storyboarding, development of instructional contents in PowerPoint templates, creating instructional videos using Zoom or Power Point application, setting up of YouTube channels, and embedding the videos on the YouTube channel.

Table 4 Rubrics for the Selection of Physics Teachers from State Ministry of Education

1	Obtain a Bachelor Degree in Physics Education/Physics Science with teaching qualification, e.g. PGDE
2	Possess a minimum of five years' experience in teaching physics
3	Possess a minimum of 15 years to stay in service before retirement. This provides a sufficient period for knowledge transfer among their fellow teachers and students.
4	Possess an internet enabled Laptop with proficiency in MS-Word, PowerPoint, and Online Meeting App such as zoom application
5	Possess a record of success of taking physics students in external competition

Draft videos from the teachers who were consistent in the training were reviewed by the research team, and detailed feedback was provided to guide iterative improvement. These activities ensured that the instructional materials met high standards of content accuracy and production quality.

Similarly, Appendix 2 contains the schedule of training on Learning Management System (LMS). The 5 days training focus on topics such as the basics of LMS, creating a course on the LMS, setting up of a course page and setting up of quiz on the LMS page. All the training were done virtually with synchronous and asynchronous approach to content delivery. After the six weeks training for all the successful physics teachers, the following conditions were used to select the physics teachers who participated in the final video recordings exercise:

1. Writing of Lesson Note in line with Culturo-Techno-Contextual Approach
2. Writing of scripts showing the necessary visual and on-screen display (storyboarding) in preparation for instructional video production.
3. Development of PowerPoint slides that will be useful for instructional video production. The numbers of lesson note, scripts, PowerPoint slides, and YouTube links are essential for qualification into the final stage.
4. Production of Instructional videos using PowerPoint or zoom application.
5. Creation of personal channel on YouTube.
6. Embedding the instructional video on personal YouTube channel and submission of the links to access the video directly on YouTube for documentation.
7. Activation of assigned portal on the Learning Management System (LMS) and creation of discussion forum, setting up quiz items, etc.

The 27 physics teachers considered suitable for the final video production were selected based on prompt submission of practical task given as assignment, the quality of script and the storyboard, PowerPoint slides, the importance of the physics topics and the contents developed, attendance during the virtual training, quality of instructional video produced, and ensuring representation across the six participating states, and the as shown in Appendix 3. The interplay of the rubrics towards the final selection was a bit complex considering the willingness of some of the physics teachers. Some teachers could not meet up with deadlines on submission of practical task as shown in Appendix 3. They were however selected for the final production due to other strengths and quality. While some teachers submitted 4 lesson notes and 4 scripts due to the volume of the assigned physics topic, some were asked to submit 3 and 2 lesson notes and scripts accordingly. One lesson note translates to one script and one instructional video at the end. A video must not exceed 10 minutes. It is important to note that all the instructional videos produced by the teachers at this stage were the outcome of the capacity building in preparation for the development of the PLMS. The teachers were asked to upload the produced video from the practical task to their personal YouTube channel and submit the links for reference purpose. Some completed the task and submitted while some did not as shown in Appendix 3.

Evaluation Stage

The evaluation stage began with the recording of final instructional videos. Makeshift studios were set up in participants' states, where teachers received preliminary coaching on managing stage fright before recording their videos. These raw videos were sent to professional editors for final production and subsequently uploaded to the Physics Learning Management System (PLMS), a dedicated online platform accessible at https://project.physicstraining.net/. The pictorial view of the platform is shown in Figure 2.

To test the usability of the instructional videos, we enrolled 298 randomly selected senior secondary school II physics students from the six participating states on the PLMS. Two major criteria were set for the selection and enrolment of students to the platform. Firstly, easy access to internet enabled computer devices such as laptop, tablets, and smart phones. This condition becomes highly imperative due to cultural position of some parents in Nigeria who will not permits their ward to access the internet for the fear inappropriate contents. Hence, the consent of their parents is required. This was achieved through the school principals and the respective physics teachers. Secondly, the maximum number of students that could be enrolled on the PLMS due to limited bandwidth as dictated by available resources was 300. Hence, 50 students were enrolled on the PLMS from each of the states. For convenience of administration of the process, a school was randomly chosen from each of the states among the participating schools whose teachers took part in the six-week long capacity building. The selected students were enrolled with their e-mail address and were asked to log into the site through the same email. The students completed pre-treatment and post-treatment tests to evaluate learning gains. However, a significant proportion of students faced challenges of accessing the platform due to the unavailability of internet-enabled devices, which we documented as a limitation in the study. It is worth noting that an experimental study aimed at assessing the efficacy of the PLMS is currently ongoing and will be reported in the second phase of this study.

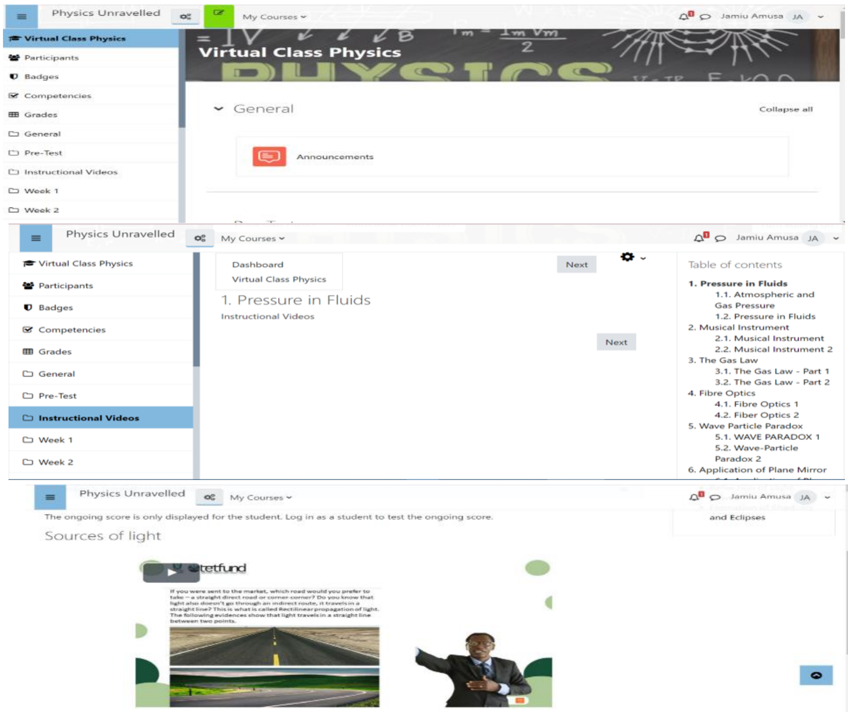

Figure 2 Pictorial Illustrations from the Pages of the PLMS

DISCUSSIONS

Deployment of PLMS for Learning - https://project.physicstraining.net/

Following the completion of enrollment of physics students on the PLMS, the learning site is now opened for use. Qualified students were enrolled mainly through their functional email address. Presently, the inclusion of the National Identity Number (NIN) during enrollment has not been actualized as proposed. At the pilot testing stage of the project which coincide with the research phase, it was observed that many of the students who were enrolled did not login due to various constraints. The most prominent among the reasons is the students lack of access to internet enabled device. Despite the huge efforts of the physics teachers in ensuring that students make use of their parents' phones to access the learning resources, only 57% of the students were able to login into the site. The remaining 43% never attempted to login. Enrolled students were instructed to login using their email address without the extension. For example, if the email address is mgazali@gmail.com, the username will be mgazali, while PHY1234 was given as the default password for all. Students were further instructed to change the password to a preferred one after logging in. The platform has been largely put to use during the validation exercise of the project by randomly selected physics students and teachers in a different study. It was found very useful to support learning of physics at senior secondary school level. The observed technological and infrastructural barrier have not only impeded virtual education delivery in Nigeria (UNESCO, 2020; Tamrat & Teferra, 2020), it is an impediment to the realization of the country's goal of meeting up with the 4th industrial revolution which is gradually transiting into the 5th revolution. Similar studies have also buttressed this position of digital divides along several parameters. (UNESCO, 2020; Tadesse & Muluye, 2020; Tamrat & Teferra, 2020).

The utilization of the PLMS depends largely on the availability of internet enabled devises such as smartphones, laptops and other forms of electronic devices. Unfortunately, most of the senior secondary school physics students largely depend on their parents' devices to gain access to internet. However, states such as Lagos and Osun states who had distributed android smart devices to their students at the senior secondary schools in the past were expected to have an edge over their counterparts in other states who have not done so. It must be emphasized that the PLMS is a work in progress that is open for improvement and additional resources. As long as Nigerian students are having direct access to physics instruction from qualified physics instructors, there will be huge expectation in the level of improvement in students' performance on the whole.

Product (PLMS) Implementation

After the delivery of the Physics Learning Management System (PLMS) to the sponsor, Tertiary Education Trust Fund (Tetfund), discussion around the implementation and sustainability becomes imperative. At present, considering the subscribed bandwidth for the current project and possible population of secondary school physics students who may seek enrolment on the platform, it is very clear that site may become highly unproductive if it is populated beyond the carrying capacity. Hence, the bandwidth and duration of subscription need to be reviewed.

In the 21st century educational landscape, PLMS stands as versatile platform that can streamline physics learning processes, facilitate individualized learning which allow students to learn at their pace and engage with other students (Al-Fraihat, *et. al*.,2020). Generally, Leaning Management System (LMS) is well noted for accessibility and flexibility, instructiveness, personalized learning structure, efficient assessment and feedback, and collaborative learning opportunities (Wang & Wu, 2019; Martin & Ndoye, 2016). These arrays of benefits call for an enduring implementation strategy to ensure the success of the project. Without doubt, accessibility to the PLMS will be made free to all students in Nigeria as long as they have their NIN. The decision about the students beyond the shore of the country may be left for the sponsor to make. However, making the learning resources free without any forms of discrimination will amount to contribution to the development of knowledge in science. This has been advocated for in research literatures (Mishra, 2017; Wiley & Green, 2012). For unrestricted access to the PLMS in this study, there is a need for expansion in bandwidth and subscription for a long period of time.

The research team will continue to handle the administration of the site. Regular updates in line with international best practices and prompt response to change in physics curriculum will be ensured. This response will be research-driven as all relevant stakeholders – students, physics teachers, and relevant policy makers will be fully involved in upgrading the learning resources. Intensive sensitization on the adoption of PLMS to support the learning of physics at the secondary school level needs to be embarked upon. This becomes very necessary to create awareness among parents on the need to support their children in the new direction of learning. Unarguably, the gap in digital literacy between the digital natives and immigrants still persist (Kirschner & De Bruyckere, 2017). Some parents could not comprehend how effective learning could be achieved through smart phones. Although, the level of indiscipline in the use of smart phones among the young ones is highly worrisome. The fear of been swayed into internet related crimes and forms of immoralities has compelled many parents to prevent their wards from accessing internet enabled smart phones (Okoiye, et. al., 2015). This indeed, is an impediment to smooth implementation of PLMS. It needs to be addressed holistically. The involvement of seasoned counselors is required at this point.

The smooth implementation of PLMS will also require understanding of socioeconomic status of the physics students. This demography is important for consideration as some physics students could not participate in the pilot test phase due to lack of fund for data subscription. It was argued that their parents could not pay for data subscription after granting them access to their phone. Despite the preliminary engagement with some the parents on the benefits entrenched in the use of PLMS to study physics, some still failed to support their children. Hence, the issue of universal acceptance of LMS, with specific reference to Nigeria context need to be re-examined.

Pedagogical Implications of Physics Learning Management Systems (PLMS)

The Physics Learning Management System (PLMS) has a profound pedagogical implication, reshaping the learning of physics at the senior secondary school level. First and foremost, the total reliance of learners on their teacher will automatically be put to check on the introduction of PLMS. Physics educators now possess a powerful tool to enhance teaching and learning experiences among students. The key pedagogical implications of using PLMS can be viewed from its impact on personalized learning, active engagement, and formative assessment. PLMS platforms promotes personalized learning experiences by allowing educators to channel instruction to individual needs, preferences, and learning styles. Through the use of data analytics and adaptive learning algorithms, LMS generally can track students' progress, identify learning gaps, and deliver targeted interventions in real-time. This personalized approach enables students to learn at their own pace, receive individualized support, and engage with content that is relevant and meaningful to their interests and abilities. With special consideration to perceived difficult concepts in physics as reflected in this study, learners can access the PLMS with varying intentions on the topic that is considered challenging. If effectively deployed, PLMS platforms provide opportunities for differentiated instruction, enabling educators to offer diverse learning pathways, resources, and assessments to meet the varied needs of students within a single classroom. For example, students who require additional support can access remedial materials or scaffolded assignments, while advanced learners can explore enrichment activities or pursue independent research projects. By accommodating the diverse needs of students, PLMS promote inclusivity, equity, and academic success for all learners.

If effectively deployed, PLMS could foster active engagement by providing interactive and collaborative learning experiences that transcend traditional classroom boundaries. Through features such as discussion forums, multimedia resources, virtual labs, and collaborative projects, students can actively participate in their own learning process, construct knowledge collaboratively, and develop critical thinking skills. It is important to note that some of the features listed in this paragraph, such as discussion forum, virtual laboratory is yet to be functional on the PLMS. Furthermore, all the engagements on the PLMS are largely asynchronous in nature. This limitation may not give room to peer-to-peer interaction and reflection which promote higher-order thinking skills and cultivate a sense of community among learners. Discussion forum hosted on LMS platforms enable students to engage in meaningful discourse, share perspectives, and debate complex issues asynchronously.

One fundamental aspect of teaching and learning exercise is the assessment. PLMS support formative assessment practices by providing the teachers with timely and actionable feedback on student learning progress. Some of the self-assessment exercises are contained toward the end of each of the instructional video. Other assessment tools include the online quizzes, polls, surveys, and self-assessment tools, which could be taken pre and post the instructional video. While these resources are being accessed, physics teachers could also assess students understanding in real-time by identify common misconceptions, and adjust instruction accordingly. Moreover, LMS platforms streamline the assessment process by automating grading and providing instant feedback to students, allowing them to track their progress, monitor their performance, and reflect on their learning outcomes. By receiving immediate feedback, students can identify areas for improvement, revise their work, and engage in metacognitive strategies that promote deeper learning.

The Physics Learning Management System (PLMS), has transformative pedagogical implication on science education landscape. By harnessing its capabilities, physics educators can activate a dynamic, interactive, and student-centered learning environment that promote academic excellence while using students' cultural context to prepare them for success in the digital age.

CONCLUSION

The main product from this study is the development of a learning resources called Physics Learning Management System (PLMS). The implementation of a Physics Learning Management System (PLMS) offers promising opportunities to enhance teaching and learning experiences by providing students with access to interactive resources, personalized learning paths, and collaborative learning environments. By leveraging the capabilities of PLMS, science educators can empower students to overcome conceptual barriers, engage actively in their learning process, and achieve deeper understanding and proficiency in physics. Students have the opportunity of learning the perceived difficult topics in physics from several professionally trained physics teachers who were also trained in use of Culturo-techno-contextual approach to teaching physics.

With the deployment of this learning resources, students can learn at their comfort zone, convenient time and their chosen space and pace. Moving forward, further research and development efforts are needed to refine and optimize PLMS platforms, upgrade the content to specific curriculum requirements, and evaluate their effectiveness in improving students' learning outcomes and performance in senior secondary school physics. Overall, the development and utilization of PLMS represent a significant step towards transforming physics education and equipping students with the knowledge and skills needed for success in an increasingly digital and technologically-driven world. The study has provided a methodological template for the development of Learning Management System (LMS) in other science subjects such biology, chemistry, mathematics and so on. The empirical reports on the efficacy of the PLMS will be presented in subsequent publication.

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DATA AVAILABILITY STATEMENT

Data will be made available on request.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests on the content of this article.

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Appendix 1: Training Schedule on Instructional Video

Topics	Training Activities	Participants' Tasks	Duration/Days
Basics of instructional video	Presentation by the facilitator	Interaction with the facilitator and peers	**Day1: Monday 8th May, 2023** **Morning Session**- Watch Lesson Video **Afternoon session** – **Opening Ceremony – 15 Minutes** **1st Life Interaction**
Stages in video production	Presentation on the pre-production, production, and post-production stages.	Discussion on which of the stages should be considered most critical and why	**Day2: Tuesday 9th May, 2023** Morning Session- Watch Lesson Video Evening session – Life Interaction
Script writing	Walking participants through the stages in script writing. Practical demonstration and interaction	Participants are to select a topic and write a script	**Day 3**: **Wednesday 10th May, 2023** Morning Session- Watch Lesson Video Afternoon session – Life Interaction Morning Session- Watch Lesson Video Afternoon session – Life Interaction
Storyboarding	How to design a storyboard	Based on the selected topic, participants are to design a storyboard indicating the media to be used for the video.	**Day 4: Thursday 11th May, 2023** Morning Session- Watch Lesson Video Afternoon session – Life Interaction Morning Session- Watch Lesson Video Afternoon session – Life Interaction
Practical Task		Participants work on Practical Task	**Day 5: Friday 12th May, 2023**
Review and Feedback on Practical Task		Review and Feedback on Practical Task	**Day 6: Saturday 13th May, 2023**
Review and Feedback on Practical Task		Review and Feedback on Practical Task	**Day 7: Sunday 14th May, 2023** Participants to work on Practical Tasks assigned to them Watch Lesson Video Afternoon session – Life Interaction
Creating Instructional Video with PowerPoint. Selecting appropriate media	Presentation on the considerations in selecting appropriate media.	Participants are expected to select appropriate media for the video production based on the topic.	**Day 8: Monday 15th May, 2023** Morning Session- Watch Lesson Video Afternoon session – Life Interaction
Uploading of video to the YouTube and embedding the link on the course page	Demonstrate how to upload the video to YouTube and embed the link on the course page.	Participants are to upload the video to YouTube and embed the link on the course page	**Day 9: Tuesday 16th May, 2023** Morning Session- Watch Lesson Video Afternoon session – Life Interaction
Methodology - Culturo-Techno-Contextual Approach (CTCA)	Train physics teachers to be able to deliver powered lesson using CTCA	Prepare and deliver lessons on difficult concepts in physics using CTCA	**Day 10: Wednesday 17th May, 2023** Morning Session- Watch Lesson Video Afternoon session – Life Interaction Morning Session- Watch Lesson Video Afternoon session – Life Interaction
Practical Task on production of instructional videos and uploading to YouTube			

Appendix 2: Training Schedule for Phase 2

Topic	Pre-Class Activities	In-Class Activities	Post-Class Activities	Facilitators
The Basics of LMS and how to log in to the LMS	An instructional video on the topic will be available to the participants to watch before the live class.	Participants interact with the facilitator(s) based on the topic.	Participants are expected to respond to discussion forum posts after the live session. The discussion also continues on the WhatsApp Group Page	**Day1: Thursday 8th June, 2023** **Morning Session (8:00am – 11:00am)** Watch Lesson Video **Afternoon session (4:30pm – 6:00pm)** Life Interaction
Creating a course on the LMS	Participants watch the instructional video on the topic before the live class.	Practical demonstration and interaction	Discussion forum activities	**Day2: Friday 9th June, 2023** **Morning Session (8:00am – 11:00am)** Watch Lesson Video **Afternoon session (4:30pm – 6:00pm)** Life Interaction
Setting-up a course page	Participants watch the instructional video on the topic before the live class.	Practical demonstration and interaction	Participants are to set-up the course page on the VLE	**Day3: Saturday 10th June, 2023** L**Morning Session (8:00am – 11:00am)** Watch Lesson Video **Afternoon session (4:30pm – 6:00pm)** Life Interaction
Setting-up a quiz on the VLE	Participants watch the instructional video on the topic before the live class.	Practical demonstration and interaction	Participants are to set-up a quiz on the course page.	**Day4: Monday 12th June, 2023** **Morning Session (8:00am – 11:00am)** Watch Lesson Video **Afternoon session (4:30pm – 6:00pm)** Life Interaction
Setting-up discussion forum	Participants watch instructional video on the topic before the live class.	Practical demonstration and interaction	Participants are to set-up a discussion forum on the course page.	**Day5: Tuesday 13th June, 2023** **Morning Session (8:00am – 11:00am)** Watch Lesson Video **Afternoon session (4:30pm – 6:00pm)** Life Interaction

Appendix 3: Physics Teachers Practical Task

SN	ASSIGNED PHYSICS TOPIC	LESSON NOTE (4)	SCRIPT (4)	PPT (4)	VIDEO ON YOUTUBE (1)	FINAL SELECTION
	EKITI STATE PHYSICS TEACHERS					
1	Pressure in Fluids	2	2		**NO SUBMISSION**	**SELECTED**
2	Musical Instrument	2	2	1	**NO SUBMISSION**	**SELECTED**
3	Equilibrium of Forces	4	3		https://youtu.be/Q85KTpqXIFE	**SELECTED**
4	Rockets and Satellite	2	2	2	https://youtu.be/nn8xxsSevyM https://youtu.be/Q_TdPTFz-3g https://youtu.be/rSnM9TidfMk https://youtu.be/YfSb-NiXPfc	
5	Simple Alternating Current				**NO SUBMISSION**	
6	The Gas Law	2	2	2	https://youtu.be/q8CZXddNb0Y ; https://youtu.be/w0cpnjUVcbk; https://youtu.be/P81N0kQgxf8; https://youtu.be/tj42T1vA8PA	**SELECTED**
7	Equilibrium of Forces				**NO SUBMISSION**	
	LAGOS STATE PHYSICS TEACHERS					
8	Fibre Optics	2	2	2	https://youtu.be/4t5xA-E-eBQ	**SELECTED**
9	Wave Particle Paradox	2	2	2	**NO SUBMISSION**	**SELECTED**
10	Measurement of Heat Energy	4	4	4	https://youtu.be/7yEfVMqmdBA, https://youtu.be/5ASCSGxsb1I, https://youtu.be/xEWLuRzhyY4 https://youtu.be/cdr3wkju7XY	
11	Application of Plane Mirror	2	3	1	**NO SUBMISSION**	**SELECTED**
12	Gravitational field	4	4	4	https://youtu.be/UpqFHu7Jsxc	**SELECTED**
13	Current Electricity	4	4	4	**NO SUBMISSION**	**SELECTED**
14	Rockets & Satellite	2	1	1	https://youtu.be/_VUJfkgPcnM	**SELECTED**
15	Electric Field	4	4	4	https://youtu.be/0Ql1YlNlwXw	**SELECTED**
16	Projectile	4	4		https://youtu.be/rlzhOb2-R9c	
	OGUN STATE PHYSICS TEACHERS					
17	Energy Quantization, Wave Particle Paradox	3	3	3	**NO SUBMISSION**	**SELECTED**
18	Electric Field				**NO SUBMISSION**	

continued

19	Measurement of Heat Energy	3	4	3	https://youtu.be/pocdsh5a4Dw	**SELECTED**
20	Nigerian Satellite	2	3	2	http://youtu.be/40tv1PzZFbE	**SELECTED**
21	Simple Harmonic Motion	4	1		**NO SUBMISSION**	**SELECTED**
22	Conduction through Liquid and Gases	4	4	4	**NO SUBMISSION**	**SELECTED**
23	Rockets and Satellite	2	2		**NO SUBMISSION**	**SELECTED**
ONDO STATE PHYSICS TEACHERS						
24	Gravitational field	4	4	4	https://youtu.be/1_uSbdQNqA8	**SELECTED**
25	Simple Alternating Current				**NO SUBMISSION**	
26	Magnetic Field, Electromagnetic Field	4	4	4	https://youtu.be/OCC-JmwXbc8	**SELECTED**
27	Energy and Society	4	4		**NO SUBMISSION**	**SELECTED**
28	Current Electricity	1	1		**NO SUBMISSION**	
OSUN STATE PHYSICS TEACHERS						
29	Sound Waves	4	4	4	https://youtu.be/NXg9mqFNk30 https://youtu.be/wRudScfjraM	**SELECTED**
30	Light Waves	3	3		**NO SUBMISSION**	**SELECTED**
31	Equilibrium of Forces	4	3		**NO SUBMISSION**	
32	Current Electricity	4	2		**NO SUBMISSION**	
33	Projectile	3	3		https://youtu.be/WSeJgXd9FhE	**SELECTED**
34	Basic Electronics	4	4	4	**NO SUBMISSION**	**SELECTED**
35	Measurement of Heat Energy	4	4		**NO SUBMISSION**	
OYO STATE PHYSICS TEACHERS						
36	Electromagnetic Field, Basic Electronics	4	4	1	**NO SUBMISSION**	**SELECTED**
37	Simple Harmonic Motion	2	2	1	**NO SUBMISSION**	
38	Sound Waves	4	4		**NO SUBMISSION**	**SELECTED**
39	Energy and Society, Basic Electronics	4	4	3	**NO SUBMISSION**	**SELECTED**
40	Musical Instrument				**NO SUBMISSION**	