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Design of an Attention Monitoring Virtual Classroom, With Retraction Mechanism for Students' Active Participation

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ABSTRACT

Using available intelligent virtual classroom systems in teaching a conventional Nigerian undergraduate program comes with a major challenge of managing and monitoring over populated students which gave rise to the development of the Interactive, Intelligent Virtual Classroom. Object-oriented analysis and design methodology (OOADM) was adopted for the study and five modules was developed to achieve the objectives of the design. An Artificial Intelligent model was trained to identify learners' distraction using body posture, eye closure, mouth opening, and body presence. Captcha mechanism was used to confirm distraction while an automated phone call was used to retract distracted learners back to an ongoing class session. Chat GPT Large Language Model was used through its Application Programming Interface to reenforce learning, provide counselling and generate reports. A firebase real-time database was used to hold the data while a web application was developed for user interface. The system was able to identify distraction and recall learners back to class. It was also able to interact with the distracted learners to gather more information as to the cause of their distraction which it further used to provide informed counselling.

Keywords: *Attention Monitoring, Automated classroom phone-call, Intelligent Classroom, Learning Enforcement, Classroom Retraction, Virtual Classroom.*

1. INTRODUCTION

The transformation of educational paradigms in the digital era has prompted the emergence of technologically advanced learning environments, among which the Intelligent Virtual Classroom (IVC) represents a significant evolution. Rooted in the convergence of artificial intelligence (AI), machine learning (ML), and learning analytics, the IVC constitutes a dynamic, interactive, and adaptive digital space designed to replicate and, in some aspects, enhance the pedagogical efficacy of traditional classrooms [1]. From a theoretical standpoint, the deployment of IVCs aligns with the principles of constructivist and socio-cognitive learning theories, which emphasize active engagement, collaboration, and contextualized knowledge construction. By leveraging adaptive content delivery and multimodal interaction (e.g., via speech recognition and visual analytics), IVCs facilitate differentiated instruction that can respond to diverse cognitive and emotional learner states [2]. Researchers have discovered that attentive and engaged learners (active participants) perform better than their peers [3]. Ideally, educators must keep track of each student in the lecture hall and adapt to their requirements to stimulate their attention during instruction. However, lecturing in a crowded classroom makes keeping track of each students' attention challenging. Studies have shown that, instructors might not continually be aware of the learners' concentration/engagement in large classrooms [4], which may influence their academic progress. This new system will address these challenges.

Motivation

Educational institutions are striving towards digital transformation strategies, thus a critical need for rigorous, interdisciplinary inquiry into the pedagogical and technological, dimensions of intelligent classroom adoption and implementation, particularly with managing overpopulated students(learners). The over population of undergraduate students in Nigerian Higher Institutions makes it difficult to manage a physical classroom much less a virtual class, as to ensure that all your learners are attentive and being monitored. Thus, the proposed system is such that present a measure to keep students in check.

Aim

This work situates itself within this emerging landscape, seeking to develop an interactive, intelligent virtual classroom, with attention monitoring for enhanced learners' active participation and improved performance. This work aims to inform both scholarly understanding and practical design of AI-enhanced virtual learning environments.

Conceptual framework

Interactive in computing involves allowing a two-way flow of information between a computer and a computer-user. Interactive classroom typically incorporates videoconferencing technologies, collaborative whiteboards, breakout rooms, real-time polling, and chat functions. These tools enable educators to facilitate meaningful discourse, provide instant feedback, and monitor learner participation in real time. This work intends to eliminate human/educators' interference and interaction using Artificial Intelligence (AI). Intelligent classrooms are technology-driven, AI enhanced systems that collect and analyze leaners data to provide actionable insights. This allows for early intervention in cases of academic struggle and more effective instructional planning [2]. As educational institutions increasingly adopt digital transformation strategies, the interactive intelligent classroom stands out as a promising solution to address the evolving needs of 21st-century learners

2. REVIEW OF RELATED LITERATURE

The study by [5], suggested a software component for tracking learners' attention during online lectures using machine learning and computer vision. The experimental results indicated positive feedback, and the module provided useful information for improving lecture delivery. It proposes further research to determine how these tools affect learning outcomes and their capacity to detect exam cheating. In a work by [6], students who enrolled in online classes had their head positions, levels of drowsiness, and yawning tracked using computer vision. The system demonstrated a high level of accuracy and could be included as a predictive analysis feature on live streaming platforms. However, the system testing was hampered by limited resources and student involvement. The system proposed that emotional analysis could be considered for upcoming enhancements. The work by [7] aimed to enable instructors visualize students' behaviour and emotional states at different levels, allowing them to appropriately manage teaching sessions by considering student-centred learning scenarios. The made use of facial recognition algorithm and trained their model using machine learning approach. Their results showed a promising performance with 76% average accuracy. [8] used virtual reality systems to monitor students' attention in a distanced learning environment; however, it was unsuitable for classroom environments. [9] used skeleton pose estimation and person detection techniques to recognize student behaviour. Their system used the Open Pose framework for skeleton detection, and they used the deep neural network to calculate the number of students in a classroom and classify their actions accordingly. Research by [10] showed a 10-15% improvement in student attendance when automated calls were used as part of an early warning system, particularly to notify parents when students are absent. [11], developed an AI-driven corporate learning system that uses personalized learning reinforcement for professional training (e.g., healthcare, banking). It uses large language models (LLMs) to generate targeted assessments based on learner history and reinforces weak areas with automated quizzes and interactive review. Carnegie Learning, MATHia plus LLMs system, developed by Carnegie Mellon University uses adaptive math software integrating LLMs for personalized reinforcement. It was developed to monitor student progress and provides just-in-time hints or feedback. It also tracks misconceptions and reinforces through immediate corrective feedback [12].

Extracts from the review

From the reviewed systems, most of them have used posture monitoring in measuring learners attention but none of them has used an external actuator like the captcha or a human confirmation like the call answering to affirm and classify the level of distraction. From the literatures reviewed, it was gathered that LLMs has been deployed in education to assist learners through tutoring and providing solutions to difficult questions (teaching assistant). It was also found to be used for personalised learning reinforcement for professional training (e.g., healthcare, banking). It was used to generate targeted assessments based on learner history and reinforces weak areas with automated quizzes and interactive review. There is no documented literature where it was been used in a classroom technology to interpret distraction details and offer learning reinforcement through human-computer interaction and counselling based on personalized data. It was also discovered that automated phone call modules have been used in smart classroom designs in the areas of students' reporting to their guardians, study reminders, and recalling absenteeism by calling students who were absent from class. But no documented literature where it has been implemented in recalling distracted learners during a live class session.

Research gap

The existing systems are marred with the following deficiencies:

i. Existing systems lack the means of classifying level of learners’ distraction particularly by using human actuators in captcha and phone call response.
ii. The existing systems lacks the mechanism to recall or retract distracted learners back to an ongoing class session.
iii. The existing system lacks the ability to interact with the learners to ascertain the cause of their distraction.

The existing system does not provide intelligent counseling, particularly with evaluating the effect of learners’ distraction on their academic performance.

3. METHODOLOGY AND DESIGN

Materials:

i. SIM 800L GSM Module
ii. USB to TTL CH340 Module
iii. Power Module
iv. SIM Card of ISP of Choice
v. Microprocessor

Object-oriented analysis and design methodology (OOADM) was adopted in this design work.

System architecture

Figure below shows the system architecture with its communication channels, which in further publications will be broken down and interpreted.

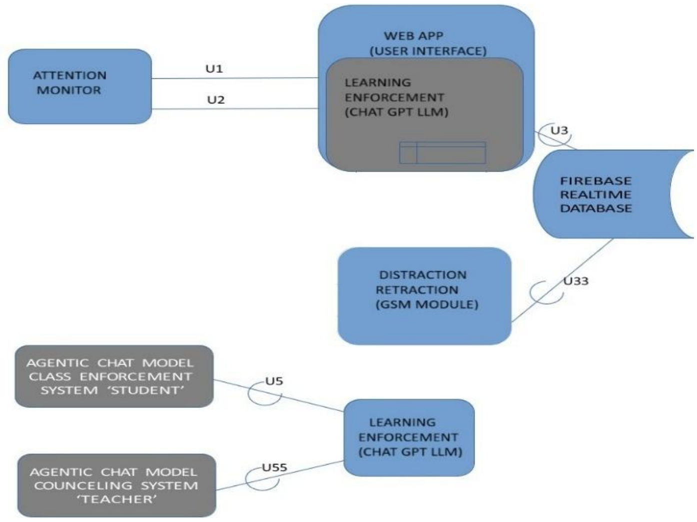

Fig. 1: System Architecture

The system is design consists of five (5) modules to include; 1. Attention monitoring module using posture detection 2. Distraction retraction module using captcha mechanism and automated phone call to recall distracted learners, 3. Learning enforcement module using chatgpt LLM to interact and counsel distracted learnerss 4. Database module using firebase real-time database to house all system data and 5. User Interface module using web application.

System flowchart

The flowchart below depicts the system process.

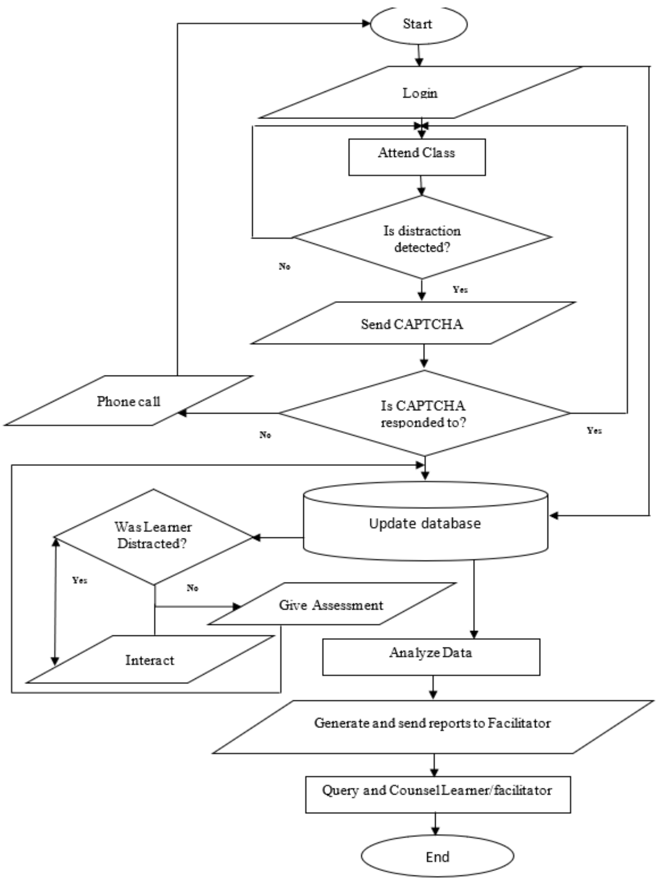

Fig. 2. System Flow Chart

The system is designed to interact with the learners' and having little or no interference from the facilitator. The learner is the main user of the system. The learner logs in, attends the class and pays attention. The system uses the camera to monitor learners' activities. These activities include facial movements, body movements, and redundancy.

This attention monitoring mechanism is incorporated into the students' profile as a plugin which in turn communicates with the system database. Its function is to observe all online students to be sure they are attentive and not distracted at all time. At any point a distraction is observed and lasts for 60 seconds, the CAPTCHA will pop-up. This pop up will be sizable enough to catch the students' attention requesting the online student to complete certain simple task within 60 seconds to keep them in the live transmission. Failures to complete the task within the time frame will automatically logout the student and update the database. Once a student is logged out, an automated phone call is made to the students registered cell phone number with a voice message prompting the student to reconnect to the class and a follow-up text message is sent. After which the database is updated. This marks the end of the first phase (Monitoring and Retraction) which takes place while learning is ongoing. The second phase (Interaction, Analysis and Counseling) commences when learning has ended. At the end of the class, the system gives a compulsory assessment to all student, but it first queries the database for all distracted student and ensures that it interacts with them personally before allowing them take the assessment. The essence of the interaction is to gather information as to the possible cause of their distraction. The causes may cut across factors like: facilitators teaching style, knowledge depth, weather and other environmental conditions, study area, work schedule / habit, study materials, Network status, geographical location etc. From the information gathered together with the distraction logs and assessment performance, the system can make analysis for individualized report. This report covers the frequency of the students' distraction, the causes and effects on the assessment performance. Finally, the analysis and report will be used for both the learners and facilitators counseling.

System usecase

Figure below is a use case diagram showing the interactions between the users of the system and the system itself

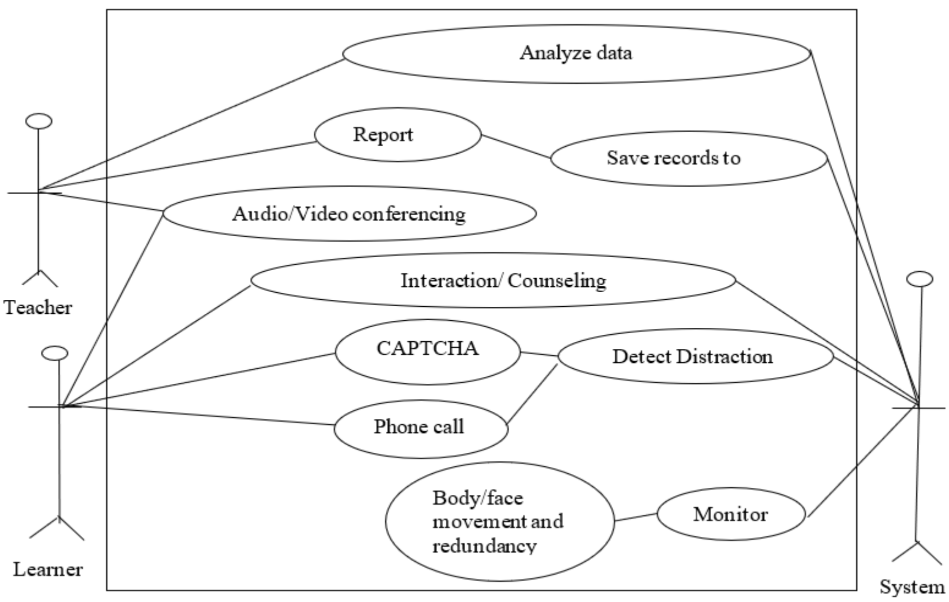

Fig. 2. System Use Case

From the figure above, teacher and learners interact directly only during live Audio and video conferencing session. Other activities and interactions are between the System modules and the users, particularly with the system monitoring and managing learners during classes without the teacher's interference. The system in turn provides reports to the teacher for further human analysis and action.

The Teacher is expected to:

i. Conduct teaching over a virtual class and create assessment for the learners
ii. Access and analyze the report generated by the system
iii. Analyze the referrals, predictions, forecasts and take actions as deemed necessary

The learners are expected to:

i. Study while the virtual class is ongoing and avoid distractions.
ii. Respond to CAPTCHA anytime it pops up.
iii. Respond to phone call anytime the system calls.
iv. Carry out assessments.
v. Interact with the system about distraction details and provide answers to inquiries made by the system.

The system is expected to perform to:

i. Monitor the learners' activities.
ii. Detect learners' distractions.
iii. Recall the distracted learner.
iv. Automatically store all data and actions on the database.
v. Carryout Analysis on all data stored.
vi. Interact with the learner and provides counseling.

4. SYSTEM IMPLEMENTATION

The system was implemented in the same five (5) design modules which are briefly discussed below but will be detailed in distinct further publications;

Attention Monitoring Module

Firstly, a video bot was developed to collect data on leaners' Posture (slouching detection), Eye closure (sleepiness detection), Mouth opening (yawning/talking detection) and Body presence (learner leaving seat). This data was captured over various sessions of controlled classroom environment and the data was used to train a model on how to identify distraction. A 60-seconds captcha mechanism was further used to confirm distraction.

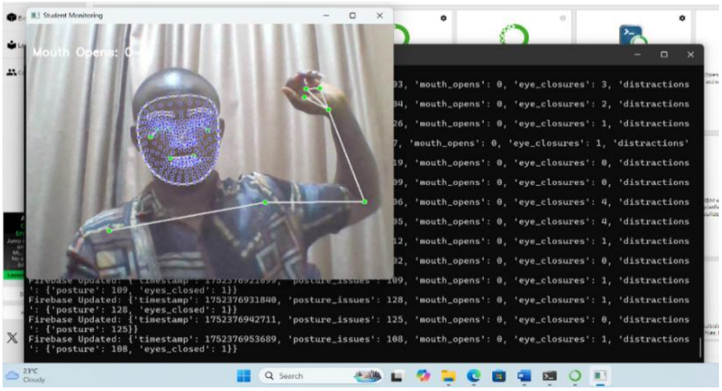

Fig. 4. Video/image capturing bot

The bot in fig. 4 above took snapshots of learners' posture at 10secs interval. These snapshots were updated to the Firebase Realtime Database with timestamps and later used to train a distraction recognition model. This model was further mapped over a mediapipe library model designed by [13] before integrating it into the system to monitor attention by identifying distraction among students/learners.

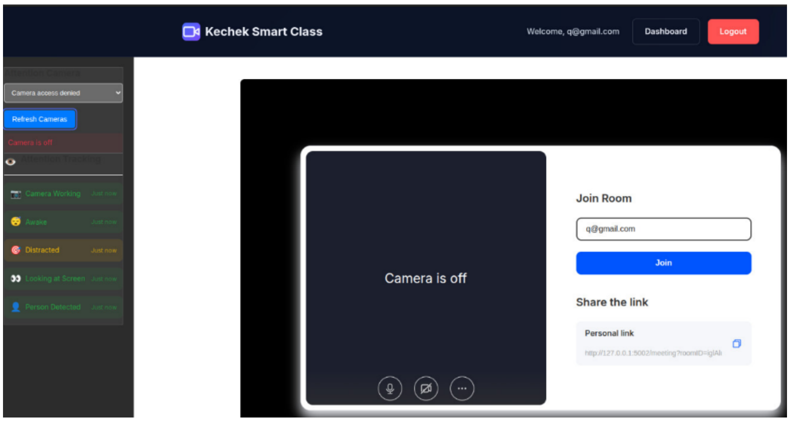

Fig. 5. Attention Monitoring module in running state

Fig. 5 shows the attention monitoring interface in its running state. From fig. 5, we can see five indicators by the left side of the screen, representing the camera status and the four distraction matrices. The first indicator signals when the monitoring camera is working or not, the second indicator signals when the learners' eyes are closed for a long period, the third indicator signals when the learner has been talking or yawning frequently for a long period of time, the fourth indicator signals when the learner is looking away for a long period of time or not having a good sitting position while the fifth signals when the learners' body is not within camera sight.

Attention Retraction Module

Achieving the attention retraction module required the integration of both software and hardware components. A user interface (software component) was created for the CAPTCHA mechanism, while the materials (hardware components) listed in VII above was assembled to create the GSM module. These two parts form the attention retraction module.

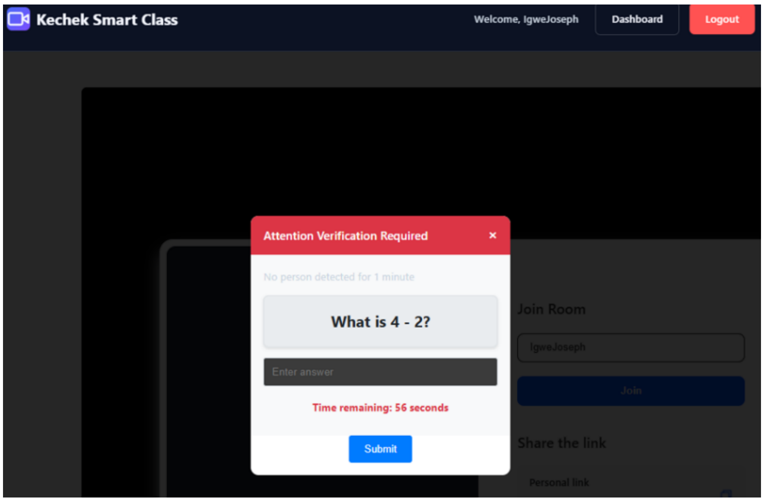

Fig. 6. Captcha screen

Fig. 6 shows the CAPTCHA mechanism used for distraction confirmation and attention retraction. Whenever high distraction is identified and the student remains distracted for up to 30 seconds, a small message appears informing the student of the identified distraction and requesting them to stop being distracted and pay attention. If the student fails to regain attention for another 30 seconds making it a total of 60 seconds duration of staying distracted the CAPTCHA appears. The CAPTCHA on its own lasts for another 60 seconds giving the students ample time to respond and remain connected. In the case a student fails to respond to the CAPTCHA, it is then confirmed that the student is highly distracted and cannot be retracted by a screen or visual method leading to the gsm call retraction.

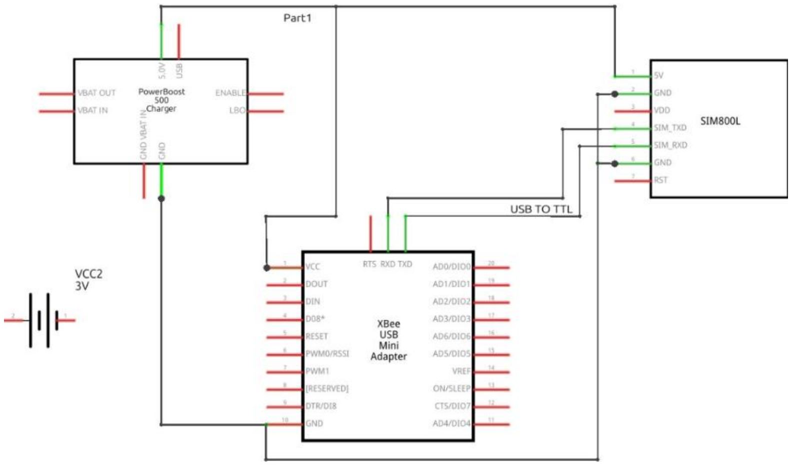

Fig. 7. GSM Module Circuit Diagram

Fig. 7 shows the circuit diagram for the GSM hardware connectivity. This module receives captcha signals from the database and places automated call to any learner who has been identified as not paying. It also calls learners whose bodies are absent from the camera range for same duration. After which, a follow-up message is sent to the defaulters and all the details are logged for further analysis.

Fig. 8. Integrated GSM Hardware

Fig. 8 shows the working state of the GSM hardware.

Learning Enforcement Module

Chat Gpt Large Language Model was used through its developers API to perform the learning enforcement and counselling functions.

The Chat Gpt enabled system was given the following instructions to tailor its application:

Note you are a Learning Enforcement Officer. Your role is to:

i. Strictly investigate why the student is not paying attention in class.

ii. Ask direct, probing questions to uncover root causes (distractions, personal issues, technical issues, lack of interest).

iii. Enforce accountability. DO NOT teach or solve problems for them.

iv. Guide them to self-reflect and commit to actionable steps.

v. Maintain a firm but professional tone. Do not be overly friendly

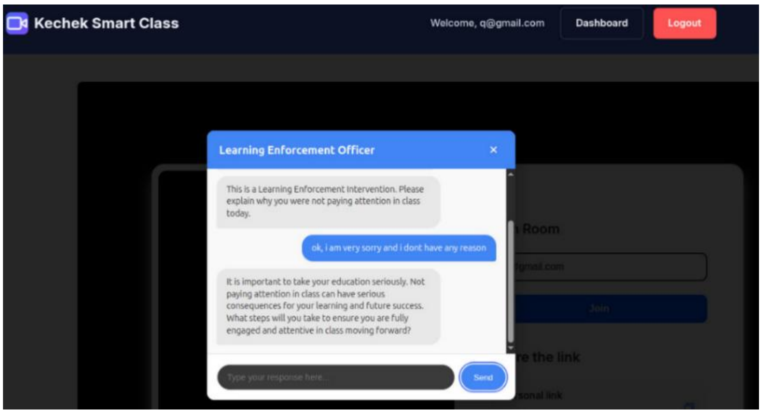

Fig. 9. Chat bot of Learning Enforcement Module

Fig. 9 above shows the chat bot of the learning enforcement module. This bot interacts with the distracted learners, analyses their responses, provides informed counselling and saves their conversation for further analysis.

Database Module

Firebase Realtime Database was used for the system development. It's cloud-based and open-source multithreaded nature supported multi-user database management system (DBMS)

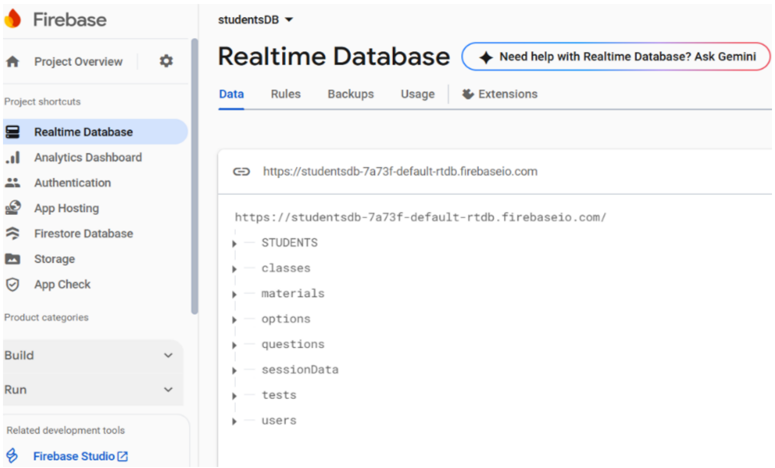

Fig. 10. Firebase Real-Time Database Set-Up

Fig. 10 above shows the firebase real-time database tables created and used by the new system to store its data.

User Interface Module

The web application was implemented with HTML, CSS and PHP framework at the front end while python programming flask framework was used at the back-end of this design to enable flexibility and control during integration.

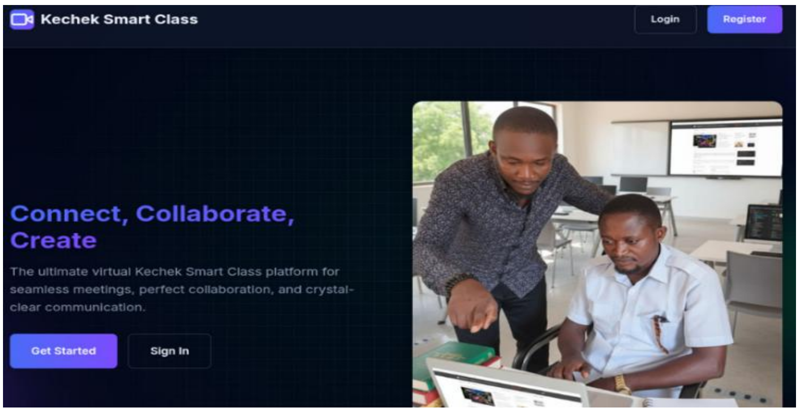

Fig. 11. Web-Application Module

Fig. 11 shows the web application that provides User Interface for the new intelligent virtual classroom. Though this web interface users can create profiles either as teacher or as student before using the system for teaching and learning.

5. SYSTEM TESTING AND RESULT

The new system was duly tested and the results tabulated as shown below.

Table no 1: Shows the system integration testing results

Module	Expected Test Result	Actual Test Result
Attention Monitoring	Identify distraction and initiate captcha	Identified distraction during learning and initiated the captcha mechanism
Distraction Retraction	Automatically call distracted learners with a voice call and send a follow-up text message	Automatically called the identified distracted learners with a voice messaged requesting the reconnect to the class and also sent a follow-up text message
Learning Enforcement	1. Interact with distracted learners seeking distraction causes 2. Counsel distracted Students. 3. Refer students to human counsellor if necessary 4. Generate Report 5. Generate teaching materials	1. Interacted with the distracted students with feedback 2. Provided counselling services to distracted students 3. Referred reoccurring cases to human counsellor 4. Generated sensitive academic report 5. Generated rich teaching materials
Database	Receive, store data and communicate with other system modules and AI agents	Received and stored all the data forwarded and could communicate with all the modules and AI agents
User Interface	Provide a user-friendly interface	Provided interface for both the teachers and students to study

Result Summary:

i. The system Identified distracted students and initiated the captcha mechanism with 98% accuracy.

ii. The system automatically called the identified (distracted) students on their mobile phone with a voice messaged requesting the reconnect to the class. This recorded approximately 70% accuracy level. The failed calls are attributed to poor network connectivity.

iii. The system sent a follow-up text message to the distracted students. This recorded approximately 95% accuracy level. The failed messages are also attributed to poor network connectivity.

iv. The system interacted with the distracted students after the class to inquire the cause of their distraction.

v. The system provided counseling services to both teachers and students.

vi. The system referred the distracted students to a human counselor.

vii. The system generated sensitive academic report from the distraction details.

Merit of the System

The proposed system will possess all the advantages of the existing system in addition to the following;

i. Inclusion of CAPTCHA for distraction confirmation
ii. Inclusion of mobile phone call services for retracting distracting learners.
iii. The Lazy facilitators will be compelled to provide an assessment before ending the class
iv. The system will force learners to pay attention during classes
v. The system will improve learners' academic performance.
vi. The system will trigger research in the area of retracting distracted learners in online classes.
vii. The system will as well trigger research in the area of learners' facilitation without human interference

Constrain of the System

The proposed system is disadvantaged as follows;

i. The system requires two cameras for its implementation on students' profile. One camera is for the video conferencing of the live class while the second camera is to monitor attention. This is because one camera could not be shared by different system functions.
ii. During deployment, some vendors such as the cloud telephone service providers refused to work with Nigerian developers and as such, we had to build the GSM hardware component.
iii. Every learner is expected to have their mobile phones close to them while studying which can lead to ringtone distractions from other callers. consequently, every learner will have to buy a separate line for studies and put off other phone lines that could cause distraction. The new line must be kept close when joining the class.
iv. Mobile Network down-time or Low phone battery can make the system unable to reach the learners through phone call. Learners must ensure that their phone batteries are charged and stay in areas with strong GSM network before joining the class.
v. In the case a student is answering a question for more than 60 second nonstop, The CAPTCHA might distract such student if detection accuracy fails.
vi. The real-time nature of the system becomes a problem in remote part of the country where internet is unstable.

6. CONCLUSION

This work situates itself within the emerging landscape, seeking to develop an interaction based intelligent virtual classroom, with attention monitoring for enhanced learners' active participation and improved performance. This work informs both scholarly understanding and practical design of AI-enhanced virtual learning environments

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