

ICT Education with Cloud-Enabled Progressive Learning: CE-PL Approach

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Abstract- This study introduces CE-PL, a novel pedagogical strategy that combines Progressive and Constructivist educational approaches to enhance cloud computing instruction. Both pedagogies emphasize student-centred learning, where students actively construct their own knowledge through experience, collaboration, and reflection. Progressive education promotes a holistic approach by integrating real-world applications and fostering social responsibility, while constructivism focuses on individual cognitive processes and the value of collaborative learning. By blending these approaches, CE-PL creates an engaging and dynamic learning environment that encourages critical thinking, teamwork, and student ownership of education. The paper outlines the theoretical foundations of CE-PL and details its practical implementation within cloud computing curricula. It demonstrates how CE-PL enhances student knowledge acquisition, engagement, and skill development, addressing the growing demand for effective and adaptive learning methods in computer science and information technology education. Additionally, the study addresses the challenges of traditional computer labs, such as time and resource constraints, workforce shortages, and facility costs. By leveraging cloud-based tools, CE-PL offers a scalable and cost-effective alternative to traditional laboratories, enabling students to gain hands-on experience essential for mastering modern computing technologies. This innovative approach not only overcomes logistical limitations but also fosters a learning environment tailored to the diverse needs of engineering and technology students.

Keywords- CE-PL (Cloud Enabled Progressive Learning), Cloud Lab, Traditional Lab, Progressive, Constructivist, Cloud Computing.

1. Introduction

Laboratory work has long been recognized as a critical component of education in computer science and information technology, offering students invaluable real-world experience. Traditionally, lab classes and workshops were used to conduct controlled experiments where students could gather data and observe systematically explainable events

using specialized instruments. However, the absence of professionals within educational institutions poses challenges in maximizing resource utilization, efficiently carrying out lab tasks, applying professional skills, and ensuring optimal learning outcomes.

This publication introduces the concept of a Cloud-Enabled Lab (CEL), designed based on the Cloud-Enabled Progressive Learning (CE-PL) pedagogy. It outlines the CEL's structure and workflow, which allows students to access the campus cloud lab anytime using a basic computer connected to the internet or institute's Wi-Fi or LAN network. The CEL includes a continuously running virtual machine, a pre-configured cloud server, a secure login portal, and a real-time interactive interface. These features enable students to log in, use lab tools, and collaborate with peers and instructors seamlessly [13].

The primary objective of this paper is to propose a strategy for developing cloud computing-based solutions to support CE-PL pedagogy. The research introduces a five-phase model for effective and efficient instruction, embodying the principles of CE-PL pedagogy [2].

1. **Keeping Up with Innovation:** The fast pace of technological advancements means that curricula can quickly become outdated. Educators need to constantly update course content and teaching methods to reflect the latest technologies and industry trends [2].
2. **Continuous Professional Development:** Teachers must engage in ongoing professional development to stay current with new tools and technologies, which can be time-consuming and costly.
3. **Limited Access to Technology:** Many educational institutions, especially in underfunded or remote areas, lack access to modern ICT resources such as computers, software, and high-speed internet.
4. **Infrastructure Issues:** Outdated or insufficient infrastructure can hinder the effective use of technology in the classroom. This includes inadequate hardware, unreliable networks, and insufficient technical support [12].
5. **Inequality in Access:** There is a significant gap between students who have access to advanced technology and those who do not. This digital divide can exacerbate existing inequalities in education and limit opportunities for students from disadvantaged backgrounds.
6. **Socioeconomic Barriers:** Students from lower socioeconomic backgrounds may face challenges such as limited access to devices and reliable internet, affecting their ability to fully engage with ICT education.
7. **Curriculum Relevance:** Designing a curriculum that is both current and relevant to

industry needs can be challenging. The curriculum must balance foundational knowledge with emerging technologies and industry practices.

8. **Effective Teaching Methods:** Developing effective teaching strategies that integrate technology and foster engagement is essential. Educators need to adapt traditional methods to incorporate ICT tools effectively. What's fascinating is that you can set up labs for students outside of the lab and after lab hours. Lab scenarios can be accessed by students anywhere, at any time, even from home or during breaks. The traditional teaching training offered by institute of education and training in India insufficient for enhancing teachers' teaching skills and professional competencies. To keep up with the fast development of communication technologies, network, teaching methodologies are lacking behind as the internet has significantly extended students' learning spaces [10]. To address these challenges, we have designed a learner centric platform leveraging cloud computing technology. This platform enables students to practice lab experiments autonomously while also receiving guidance from teachers outside of traditional classroom settings [14]. Cloud-enabled learning and development environments surpass traditional computing labs by providing superior accessibility, collaboration, and scalability. Unlike fixed-location labs, cloud-based solutions grant students and educators access to resources from any internet-connected device, supporting learning anytime and anywhere [12]. This flexibility fosters personalized educational experiences and accommodates a variety of learning styles. Furthermore, cloud platforms enable real-time collaboration, allowing multiple users to work on projects simultaneously, enhancing teamwork and communication skills. They also reduce costs for educational institutions by eliminating the need for expensive hardware and maintenance.

2. Research Objective

The objective of the proposed model is to establish a cloud-based learning environment that supports effective communication and collaboration among learners. This platform will provide access to the CEL Forum and CEL Server, based on users' specific needs and registration status. By guiding users through decision points, such as their intent to share inquiries or ideas and the activation status of their user ID, the system will direct them to the most relevant resources, including the CEL Forum Dashboard for community interaction or the User Dashboard with an allocated virtual machine for personalized learning and project work.

3. Proposed Work

CEL Model:

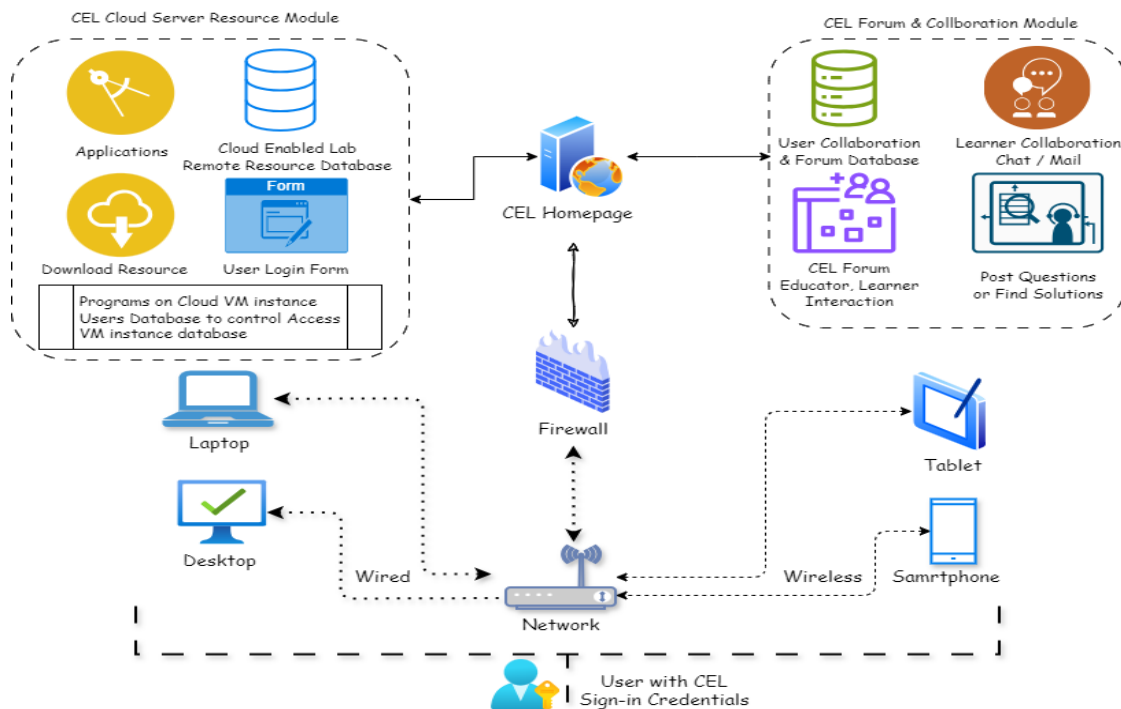


Fig. 1 Purposed Framework of the Cloud Enabled Lab (CEL) Model

The proposed framework of Cloud Enabled Lab has set up in the computer lab located in the Government College Radur, Karnal, Haryana. As per the literature and institute lab requirement, open-source software was used to setup the cloud enabled lab.

To set up the **Cloud Enabled Lab (CEL)**, we create virtual machines (VMs), configure the required hardware and software, establish user access privileges, and store these configurations in the VM repository on cloud servers. The conceptual framework of CEL is illustrated in Figure 2.

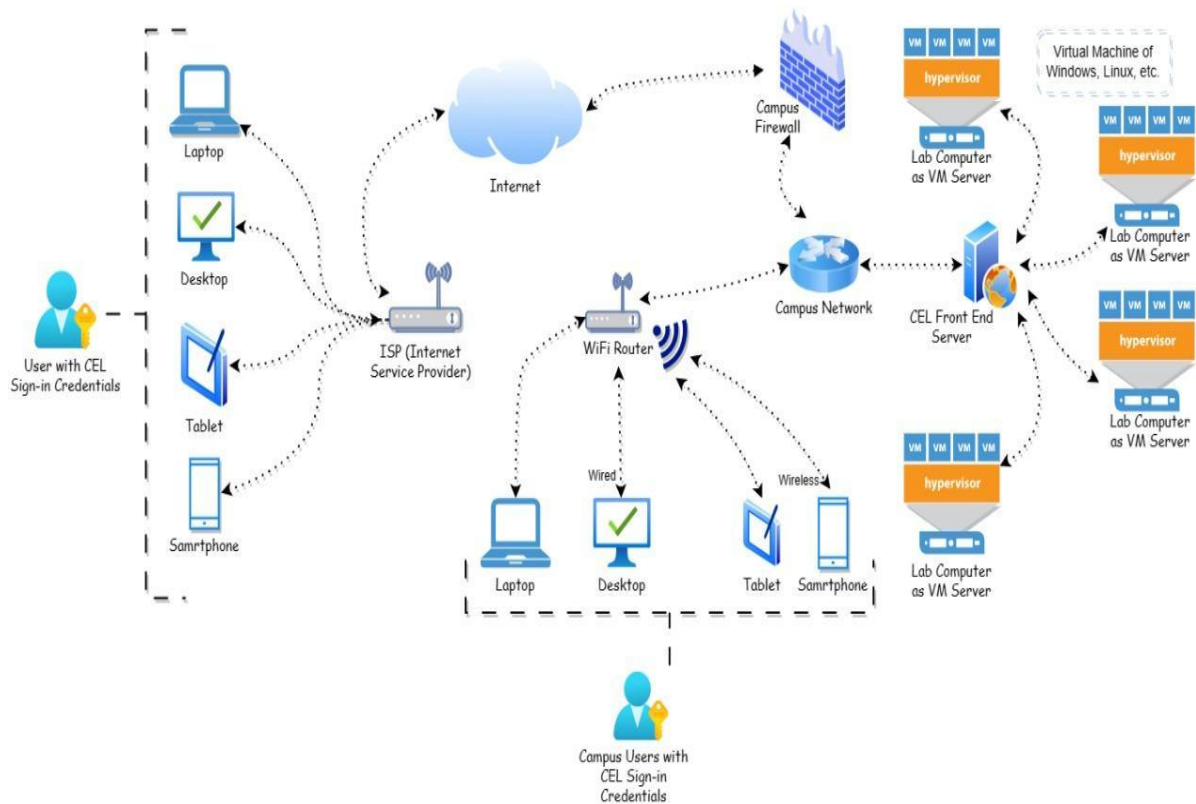


Fig. 2 Conceptual framework of CEL Server

When a student submits a request, the CEL management system, which oversees the virtual machines, present the pre-allocated machine on the homepage from the available resources. The hardware resources required to construct the CEL are defined and managed by open-source software that governs the relationship between hardware and virtual machine resources. CEL researchers designed distributed cloud servers capable of hosting 20 virtual machines using Oracle VMware VirtualBox, each configured with 4 CPU cores, 4 GB of RAM, and 10 TB of shared storage. A single cloud server can host multiple virtual machines, each with its own operating system and relevant software packages. For example, Linux and Windows (Ver 7/8/10/11) virtual machines can run concurrently on a server. Users can access these VMs through a web page which gets data through remote desktop protocol that provides a dedicated virtual environment with computing resources on the web browser.

The process begins with the user being prompted to indicate whether they have any questions or ideas to share. Based on their response, they are directed to either the CEL Forum or the CEL Server. The figure number 3 with user login flowchart illustrates the process. If the user has questions or ideas, they proceed to the CEL Forum homepage, where

a Forum Session Token is generated. Alternatively, if the user does not have questions or ideas to share, they are directed to the CEL Server homepage, and a CEL Session Token is generated.

Next, the user accesses the User Login Module. The system then checks whether the user is already registered. If the user is not registered, they must complete the registration process. Upon successful registration, their ID is activated by the CEL Administrator, and a CEL Session Token is generated for the new user. If the user is already registered, the system verifies whether their user ID has been activated. If it has not, the user must wait for activation by the CEL Administrator. Once the user ID is activated, the user gains access to either the CEL Forum Dashboard or their User Dashboard, which includes an allocated CEL Virtual Machine.

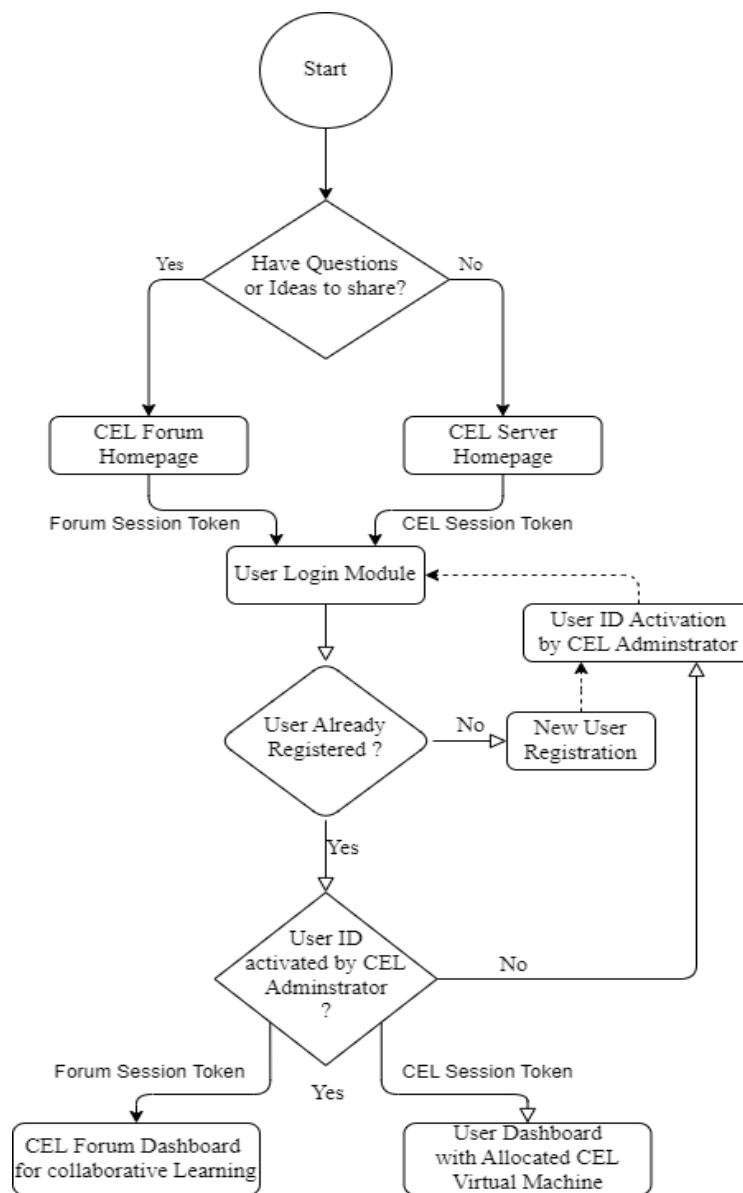


Fig. 3 User Login Process Flowchart

For computer science curricula spanning semesters, CEL offers instructional software for both Microsoft Windows and UNIX operating systems, alongside essential application software such as Java, C, C++, Notepad++, Linux, office automation tools, and other basic utilities. CEL is structured into three primary subsystems:

Cloud Lab Classroom. A virtual space for instruction and collaboration.

Cloud Computing Lab Servers. Hosts the virtual machines and supports various software environments.

Cloud Lab Client. The user/student interface for accessing CEL resources.

The CEL web portal was developed using modern technologies such as Bootstrap, HTML5, CSS, JavaScript for handling the frontend. And backend, with Node.js, PHP and MySQL for the database. Before accessing CEL resources, educators, staff, and students must register on the portal via the CEL management model and verify their identity. Once registered, they can log in using credentials provided by the university administration and access CEL resources through the web portal.

To utilize CEL, users log in to the portal with their credentials and access their allocated remote lab resources anytime, anywhere. Users have the flexibility to utilize lab resources immediately or schedule them for later use. Once logged in, they can perform experiments seamlessly, leveraging the allocated system based on their requirements. The system notifies users when their lab session is about to expire, prompting them to save their work and log off to free up resources for other users. Students and staff can access CEL resources through any web browser, such as Edge, Chrome, Firefox or any other, on a basic computer.

The underlying cloud infrastructure is managed entirely by the CEL system, requiring no control or management by end users. During lab sessions, instructors and students log into a shared virtual machine simultaneously. Once all students are confirmed present in CEL, the instructor begins teaching using the platform's components. For students who miss a class, recorded sessions are available on the portal, ensuring they can catch up later.

After completing a hands-on experiment, a teaching assistant (TA) or teacher can remotely access each student's assigned virtual machine (VM) using any remote desktop protocol. This allows them to grade assignments or provide technical assistance without being physically present in the computer lab. This flexible approach to grading and support enables teachers, students, and TAs to efficiently manage their work and teaching schedules. Addressing questions and resolving issues related to students' remote access to VMs is carried out in a more streamlined and effective manner.

If a student encounters difficulties during a practical experiment, a designated teacher or TA can log in remotely to monitor the student's VM and provide guidance as needed. The **CEL-integrated peer-to-peer communication platform** (text-based) facilitates seamless collaboration between students and instructors or TAs, allowing them to work together virtually on experiments.

CEL supports two types of experiments:

Non-Open Experiments: CEL-Server preconfigured virtual machines with specific hosts, devices, and services. Students are typically required to follow strict schedules or observe the system's operations without making changes.

Open Experiments: In CEL Forum students are granted the freedom to share their ideas with peers. This category encourages exploration and experimentation, fostering deeper engagement and learning.

By combining remote monitoring, real-time communication, and flexible experiment categories, CEL creates an adaptive and supportive learning environment that enhances both teaching and practical skill development.

Clients with Own Devices:

Clients can be the Learners of Educational Institute who need to complete their computer lab assignment, project, practical, or research work that requires specific computing resources like Hardware and Software. Client device should have some minimum system requirements such as a web browser that supports HTML5, A stable internet connection whether it could be a mobile internet or stable Wi-Fi / Ethernet connection whichever is suitable for the client. In addition to that a 1024x768 screen resolution for optimal view of cloud machine.

The CEL may be used with client device method, where the learners use their own devices or basic computer lab devices to access the cloud enabled Lab resources. CEL administrator or the educator can pre-allocate the machines to each learner as per their course requirement or alternatively de-allocate it.

To facilitate equitable access to the university's cloud enabled lab environment, the institution may provide students with basic mobile computing devices at the commencement of each semester. These devices will be preconfigured with essential software, such as a web browser, to enable seamless interaction with the Course Management System. Students will be required to return these devices to the Institution at the conclusion of the semester. A nominal fee may be levied to cover maintenance and operational costs.

Campus Wired / Wireless Network:

To provide flexible and secure access to CEL resources, a virtualized infrastructure will be implemented. Users will be able to access their assigned virtual machines, equipped with the necessary hardware and software configurations, via the campus network or the internet.

The campus network, including both wired and wireless LAN, will serve as the

primary medium for transferring audio-visual data from the CEL resource machines to user devices [11]. This approach is particularly suitable for students who prefer a remote, anytime, anywhere work environment.

The CEL may be used with local area networks (LANs) or the internet service to provide access to its virtualized infrastructure. The CEL server will utilize multiple network interface cards (NICs) to interconnect various internal networks. These networks will be assigned IP addresses within the infrastructure IP range, specifically for the VMware solution.

To ensure security and compliance, extra measures may be added such as only client devices or university-provided devices may be permitted to access CEL resources. Personal computing devices to stop any unauthorized access by the lab administrator may be restricted.

4. Educator Workflow:

The process begins with the user logging in by entering their credentials. If the credentials are correct, they are granted access to the system. The user can then perform various tasks, including user management (adding, removing, and updating user accounts), managing the CEL forum (posting and answering questions), posting additional learning resources, evaluating and grading student work, and accessing a dashboard for overall management tasks. If a live session is scheduled, the user can conduct the session, deliver content and engaging with learners through cross-questioning. After the session, they can gather feedback and review it for improvement. The user can also address any queries about the content. Once the scheduled session is complete, the user can proceed to the next step or log out of the system. (workflow presented in figure no. 4).

The Educator workflow also supports monitoring student participation on the forum and addressing unresolved queries to ensure clarity in learning. Educators can provide constructive feedback on submissions, helping learners improve continuously. The dashboard enables reviewing past sessions and refining upcoming ones while also offering sharing of ideas and active engagement among the learner for better collaboration. Educator learner both can have a common ground to share ideas and engagement. This makes the overall process more efficient, scalable, and learner-centric.

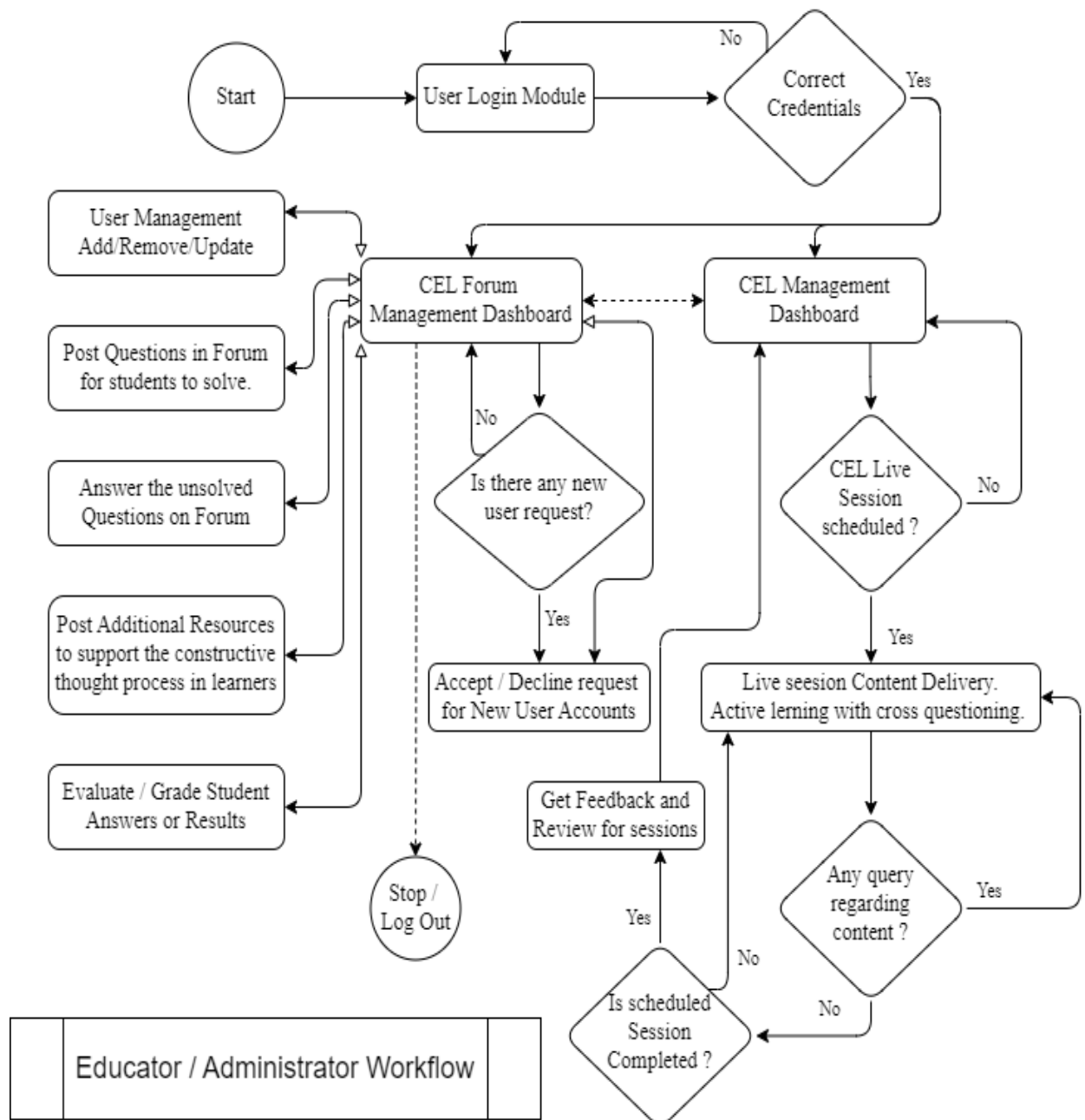


Fig.4 Educator Workflow.

Students Log-In Portal:

CEL portal prototype is designed in the JAVA the primary language used for the

server-side components, Apache Tomcat for hosting the web pages. And HTML5, JavaScript, and CSS for the creation of web-based user interface, enabling browser-based access to the CEL resources. In addition to these technologies PostgreSQL database is used to store user credentials and connection information. (workflow presented in figure No.5).

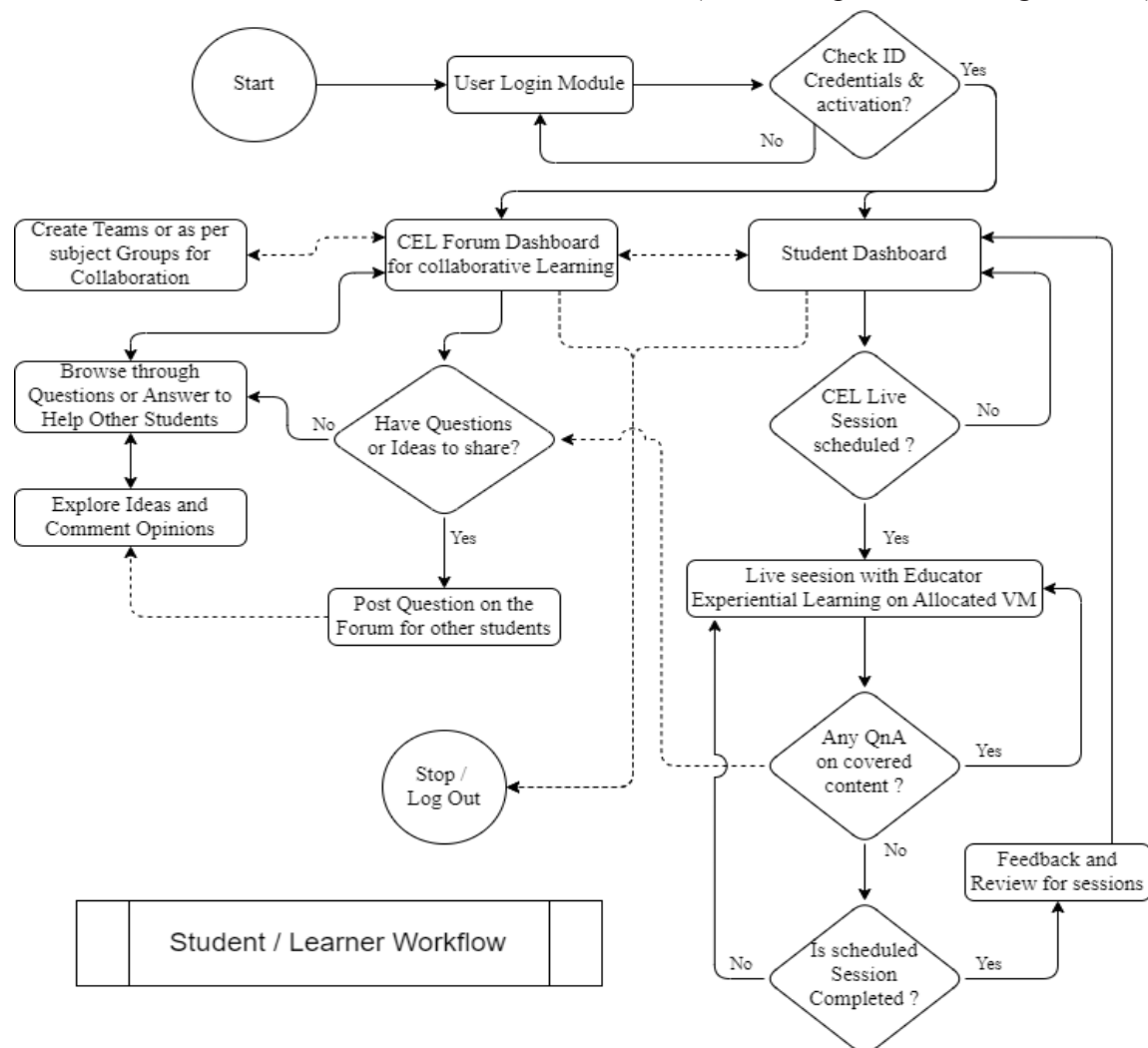


Fig.5 Student Workflow

Enrolled students on campus must access the **Campus Student Login Portal** to authenticate their credentials provided by the CEL (Cloud-Enabled Lab) Management System. Alternatively, students can sign up on the portal using their campus registration number and other basic details.

CEL portal is organized into three main components:

Teacher/Student Communication Module: Facilitates seamless interaction between students and instructors.

Virtual Machine Allocation Module: Provides information about the hardware/software configuration and credentials required to access the assigned virtual machines.

Basic Applications Module: Lists the essential applications that students need to install on their devices to utilize CEL resources effectively.

Upon successfully signing in to the CEL portal, students can choose from several options, including accessing virtual machines for research work or laboratory experiments. They can utilize the real-time coding interface to write and execute code quickly, enabling them to complete assignments efficiently. Additionally, students have the flexibility to reserve virtual machines based on the requirements of their experiments.

The login portal also offers access to **Network Storage (Storage Area Network)**, allowing students to save experiment results, documents, and related data securely. This integrated system ensures a streamlined and productive experience for students engaged in academic and research activities.

Security system:

The CEL incorporates robust security measures to ensure the protection of sensitive data and secure user access. These measures include:

- **Strong Password Policies:** Enforcing password complexity requirements and mandating regular password changes to enhance account security.
- **Encrypted Communication:** Utilizing TLS/SSL encryption for all client-server interactions to safeguard sensitive data from interception during transmission.
- **Session Timeout Management:** Setting appropriate session timeout durations to reduce the risk of unauthorized access if a session is left unattended.
- **Sensitive Data Protection:** Avoiding the storage of plaintext passwords and employing strong encryption techniques for sensitive information to mitigate potential data breaches.
- **Role-Based Access Control (RBAC):** Implementing RBAC to ensure users are granted only the permissions necessary to perform their assigned tasks, minimizing unnecessary access to resources.
- **IP Access Restrictions:** Limiting access to the system gateway by specifying allowed IP addresses or IP ranges, thereby reducing the system's attack surface.

Activity and Security Logging:

Enabling detailed logs to track user activities, failed login attempts, session durations, and security events, providing valuable insights for monitoring and incident response.

By integrating these comprehensive security protocols, CEL ensures a secure and reliable environment for users, protecting data integrity and minimizing potential risks.

Pre-Configured VM on Cloud Server:

The Cloud Enabled Learning (CEL) system offers a streamlined approach to virtual machine (VM) provisioning. Preconfigured VMs, tailored to specific course requirements, are made available to students at the beginning of each semester. This proactive approach ensures efficient resource allocation, minimizing system overhead.

The CEL administrator or lab technician assigns VMs to students based on their course curriculum and specific software needs. For instance, a first-semester MCA student might be assigned a VM with a four-core processor, 4096 Megabyte of RAM, a 50GiB storage space along with internet connectivity, and essential software like Microsoft Windows 10/ Linux and a Python compiler.

While these pre-configured VMs are designed to meet the needs of most students, the CEL system offers flexibility. Students requiring additional resources, such as increased CPU power or memory, may request an upgrade with appropriate authorization. This dynamic allocation strategy empowers students to tackle complex tasks and fosters a productive learning environment.

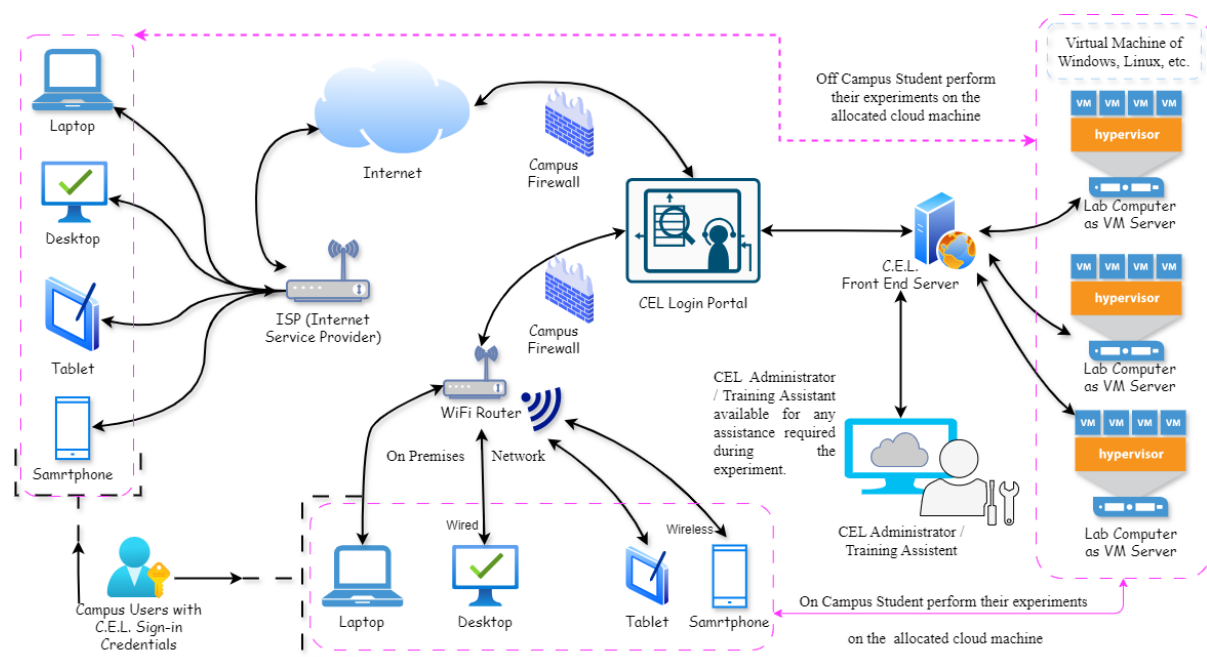


Fig. 6. Student-Teacher during Teaching

Figure No.6 describes the architecture of teaching lab session. This model consists of Teacher and Students together, where teacher deliver the subject matter using shared VM. The process requires the teacher to log-in to a VM for demonstration of subject matter or programming snippets, the student can access the shared VM's screen in collaboration with other students having restriction to view-only content at the same time; assigned for demonstration being performed. After assuring the presence of students in CEL, the teacher starts teaching the subject matter with hands on programming or other activities for better practical understanding of the subject matter by students incorporating the component of CEL system. This whole teaching process has live audio feed as well as shared screen video from the teacher and the session will be recorded on teacher's end for future references. If any of the students skip the class or need to revision, then recorded version also available on portal. This may also lead to the on-demand learning with customized content & environment.

The CEL system ensures secure login credentials, protected access through firewalls, and encrypted connections for transmitting data during sessions. The architecture also supports cross platform accessibility so that students can seamlessly join from laptop, tablets, or smartphones without performance downgrading. The CEL environment may also include collaborative features such as peer-to-peer interaction, code sharing, or group discussions that strengthen the learning experience. Teachers and administrators can monitor performance, attendance, and engagement through analytical dashboards for better evaluation of students' progress. To avoid disruption, backup support and recovery mechanisms ensure learning continuity even in case of network or system failures. Additionally, CEL can integrate with Learning Management Systems (LMS) like Moodle or Blackboard, streamlining assignment submission, grading, and feedback in one environment.

CEL system may also include on-demand Massive Open Online Courses (MOOCs) by SWAYAM which are already well organised and presented by Government of India as per New Education Policy 2020. The demonstration videos provided by the teacher may be Institution and learner centric in line with the pace of student of a specific region and their needs.

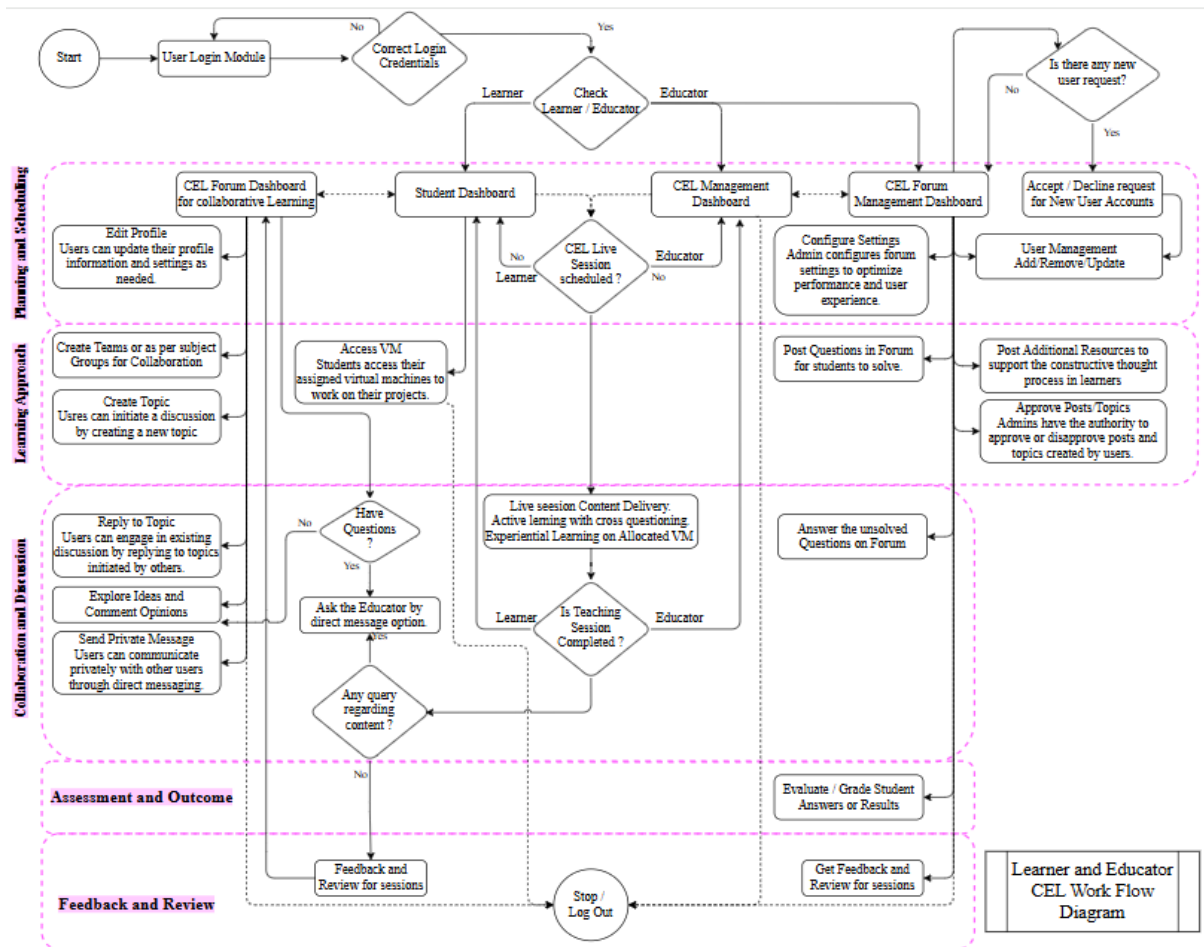


Fig.7 CEL pedagogy workflow.

Figure No-7 incorporates the five phases of CEL pedagogy with its workflow. Basically, the flowchart describes the proposed & implemented pedagogy during the Teaching using CEL. From the above flow diagram – The CEL web portal is the interface through which the teacher and student both Log-In to their account by authenticating with their credentials. Next the portal consists of tools based on different privileges of the user. The teacher has a section that contains previous session information as- problems and any other messages. Similarly on the student account there is an option for Ensuring subject matter and task to be taught today. Teacher can ensure that student(s) are online and vice versa. After both teacher and student are online, the teacher will start an instance of VM for teaching. Students are restricted to view only and learn form that generated instance in a live session. Teachers can use other

teaching material as- PPT, PDF and video, etc. After the successful completion of the lab session students can Log-In to their assigned CEL resource VM for carrying out experiments. During the assignment job the teacher or the lab assistant can monitor/observe the activities of the students and ready to solve any problem if faced by the student in real time. After the successful experiment completion student will submit the results for evaluation and exit from the system. The submitted results are evaluated by the teacher and for the next scheduled lab session he/ she will upload the teaching matter and assignment and after that can exit from the system.

Cloud Enabled Progressive Learning (CE-PL) leverages cloud computing to enhance educational methodologies rooted in Progressive and Constructivist learning theories. This approach offers several advantages over traditional methods, particularly in the context of teaching cloud computing and other technical subjects.

Conclusion

Overall, Cloud Enabled Progressive Learning (CE-PL) offers a more dynamic, interactive, and adaptable approach to cloud computing instruction compared to traditional methods. It aligns with *Constructivist* and *Progressive* educational theories by emphasizing experience-based learning, adaptability, and collaboration—key elements for preparing students for the rapidly evolving landscape of technology. The integration of cloud-enabled labs within a student-centred educational framework presents a transformative opportunity for modern learning. By providing flexible, accessible, and scalable resources, cloud technology empowers students with personalized learning experiences, fosters collaborative learning environments, and enhances the overall quality of education.

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