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A Cloud-Enabled Learning Framework for Enhancing Computer Science Education: A Five-Phase Progressive Learning Pedagogical Model

Ritu Narwal[1], Dr. Jyoti[2]
Department of Computer Science & Applications
Baba Mastnath University Asthal Bohar, Rohtak, Haryana, India

Abstract:
The rapid evolution of technology has transformed the expectations and delivery of computer science education, demanding innovative approaches that integrate both pedagogy and infrastructure. This study introduces a Five-Phase Progressive Learning Pedagogical Model embedded within a Cloud Enabled Laboratory (CEL), designed to enhance accessibility, collaboration, and skill acquisition in computer science courses. The five phases — Planning & Scheduling, Learning Approach, Collaboration & Discussion, Assessment & Outcome, and Feedback & Review — are grounded in constructivist and progressive learning theories, emphasizing active, student-centered engagement.
This research employs a quasi-experimental design to compare the CE-PL model with traditional instruction. Pre-test and post-test analyses reveal a statistically significant improvement in the experimental group, indicating that the model fosters deeper understanding, collaborative skills, and consistent engagement. While limited to one institution and one semester, findings suggest scalability across disciplines and contexts.
The paper discusses the pedagogical rationale, implementation process, and preliminary impact, highlighting the model's potential to reduce infrastructure costs, broaden access to laboratory resources, and support blended learning environments. This pilot lays the groundwork for future large-scale, multi-institutional studies to validate the model's effectiveness and explore long-term retention outcomes. Abstract:
Key Word: *Cloud Enabled Laboratory, Pedagogy, Progressive Learning, Pilot Study.*

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I. Introduction

1.1 Background

The accelerating pace of technological change continues to reshape both the expectations and delivery of higher education. In computer science and related disciplines, this shift is particularly evident, as the rapid emergence of new tools, platforms, and industry standards requires educational institutions to adapt quickly. Traditional teaching methods, often centered on static lectures and fixed-location computer laboratories, are increasingly challenged by limitations in infrastructure, access, and scalability [11].

While physical laboratories have long been a cornerstone of ICT education, they demand substantial investment in hardware, maintenance, and staffing. Moreover, such labs are constrained by timetables and location, restricting opportunities for students to engage in extended or flexible practice [16]. For many institutions, especially those in resource-constrained contexts, these challenges exacerbate the **digital divide**, limiting equitable access to high-quality practical training.

1.2 Problem Statement

Despite the proliferation of online learning during and after the COVID-19 pandemic, many computer science courses still struggle to provide the **hands-on, collaborative learning experiences** that are vital for skill mastery. Existing online tools often lack real-time interactivity, individualized learning paths, or integrated collaboration mechanisms that mirror industry practices [13]. Without such features, students risk graduating with theoretical knowledge but insufficient practical competence.

1.3 The Role of Cloud-Enabled Learning

Cloud computing presents a compelling alternative, offering on-demand access to scalable computing resources, virtualized environments, and collaborative platforms that transcend physical and temporal boundaries (Al-Rwaidan et al., 2023). By integrating cloud-based laboratories with progressive pedagogical models, educators can extend learning opportunities beyond the classroom, promote peer collaboration, and tailor experiences to diverse learner needs.

The **Cloud Enabled Progressive Learning (CE-PL) framework** builds on these advantages by merging cloud infrastructure with a structured pedagogical model. This design supports **student-centered, active learning** while addressing institutional constraints such as limited hardware, staff shortages, and timetable restrictions.

1.4 Research Aim and Pilot Scope

The aim of this pilot study is to evaluate the feasibility and short-term effectiveness of a **Five-Phase Progressive Learning Pedagogical Model** embedded within a Cloud Enabled Laboratory (CEL) in undergraduate computer science education. Specifically, the study seeks to:

- Compare student learning outcomes between CE-PL and traditional instruction.
- Examine the model's potential to enhance engagement, collaboration, and accessibility.
- Identify practical considerations for scaling the approach to multiple courses or institutions.

Conducted with 90 Bachelor of Computer Applications (BCA) students at a single institution, this study serves as an initial step toward broader implementation. While its findings are preliminary, they provide insight into both the pedagogical and infrastructural implications of adopting cloud-enabled, phase-structured learning.

II. Literature Review

2.1 Foundations of Progressive and Constructivist Learning

Progressive education emphasizes experiential learning, critical thinking, and real-world application (Dewey, 1938; Zhao, 2015). Constructivist theory complements this by positing that learners build knowledge through active engagement, collaboration, and reflection (Vygotsky, 1978; Piaget, 1973). In computer science education, these principles manifest in project-based learning, inquiry-driven problem solving, and peer-to-peer collaboration [16].

The **Five-Phase Progressive Learning Pedagogical Model** adapts these ideas into a structured sequence — from initial planning to final feedback — ensuring that students progress through a complete cycle of learning that supports both skill acquisition and metacognitive growth.

2.2 Cloud Computing in Education

Cloud computing has emerged as a transformative force in higher education, enabling scalable, on-demand access to computing resources and specialized software (Mell & Grance, 2011). **Cloud Enabled Laboratories (CELs)** allow students to run experiments, deploy code, and simulate real-world scenarios without being physically present in a lab [11].

Advantages reported in the literature include:

- **Accessibility:** Learning from any location and device.
- **Scalability:** Easily adapting resources to different class sizes.
- **Collaboration:** Real-time shared environments that support teamwork.

These affordances make cloud-enabled learning particularly compatible with progressive pedagogies, which rely on active participation and authentic tasks.

2.3 Linking the Five Phases to Pedagogical Theory and CEL

The Five Phase Pedagogical Model connects teaching theories with modern technology in a simple but powerful way. In the planning stage, teachers prepare the lessons and students get to see the problems they will solve. CEL here makes it easy to share schedules and resources. In the learning stage, students take part in live sessions or watch demos. This is where they learn the main ideas, and CEL technology allows them to join in, ask questions, or rewatch the material later.

The next step is collaboration and discussion. Students work together, share ideas, and help each other. Online forums and learning platforms make this teamwork possible even outside the classroom. After that comes assessment. Students submit their work and get graded, while teachers can track progress using digital tools. The last step is feedback and review. This helps students improve and lets teachers adjust their methods. Technology here gives quick feedback and even suggests better ways to learn. Together, these five steps show how teaching theories and technology can work side by side to make learning easier and more effective. In the end, both teachers and students benefit from this balance. It creates a learning system that feels modern, flexible, and supportive for everyone.

Phases	*Planning and Scheduling*	*Learning Approach*	*Collaboration and Discussion*	*Assessment and Outcome*	*Feedback and Review*
Role of Student	Learners should have prior knowledge about the Curriculum/ subject problems that they will learn.	Learners engage in CEL with live learning session and learn about subject matter	Learner Collaborates on the CEL Forum and discuss about the problem with fellow learners.	Lerner's submit their work to the educator at the end of experiment.	Prove feedback for the performance or the test.
Andra-gogical Aspect	Problem Solver oriented	Learn, gain concept.	Collaboration, Constructivism	Task completion.	Desire to improve the system
Andra-gogical Aim	Learners get to know about the problems/matter to be taught.	Learners will be ready to solve their assigned problems as per concept.	Team work, Progressive Learning	Perform a task within the timeframe and submit assignment	Provide feedback receive the grades.
Role of Educator	Plan the schedule the subject matter, CEL resources	Deliver the live session with demonstration of the technical requirements or as per curriculum.	Support the learner on their learning quest, Design and post the problem to solve.	Assess the results submitted by the learners.	Provide feedback for review.
Peda-gogical Aspect	Resource and Subject Material	Create demo or session materials.	Guide the learner, keep them engaged on the topics.	Keep the track of work progress of learners.	Improve the system and process with the help of feedback and reviews.
Peda-gogical Aim	Prepare learners to be problem solver	Engage the learner in the session and deliver the required knowledge	Build a constructive learning environment for learners.	Create a progress plan for each learner.	System improvement with the insights given.
Key Con-sideration	CEL resource may be designed in accordance with the available curriculum or the subject requirement.	CEL live sessions are subject to the curriculum and recorded sessions may be given to learners for review.	CEL Forum requires moderation by the educator to keep the discussion on track.	The assessment of the work can be done on the forum by providing upvotes or changing the rank of the learner.	The feedback and review may be taken from the forum or the CEL cloud for improve-ment in either system.

Table 1: Five-Phase Progressive Learning Pedagogical Model

Phase 1: Planning & Scheduling

Effective planning ensures that both learners and instructors have clear objectives, timelines, and access to the necessary resources. In progressive pedagogy, this phase aligns with **advance organizers** and **goal-setting strategies** that help learners contextualize upcoming material (Ausubel, 1960). In a CEL environment, this planning is facilitated by pre-configured virtual machines, curated resources, and instructor-prepared schedules.

Phase 2: Learning Approach

This phase focuses on delivering core knowledge and skills through live demonstrations, guided practice, and interactive resources. Constructivist approaches recommend **scaffolded learning**, where students gradually move from supported tasks to independent application (Bruner, 1960). Cloud-based environments allow instructors to embed multimedia, run simulations, and provide immediate feedback during live sessions.

Phase 3: Collaboration & Discussion

Collaboration is central to both progressive and constructivist learning. Research shows that peer discussion fosters deeper understanding, especially in technical subjects [13]. In CEL, discussion forums, shared virtual workspaces, and collaborative coding platforms support synchronous and asynchronous interaction.

Phase 4: Assessment & Outcome

Formative and summative assessments are essential for tracking progress and providing feedback. Cloud platforms facilitate **continuous assessment** by logging student activities, enabling instant grading, and generating analytics dashboards [17]. This aligns with progressive ideals of iterative improvement rather than one-time evaluation.

Phase 5: Feedback & Review

Feedback closes the learning loop, helping students reflect on strengths and areas for growth. Constructivist pedagogy emphasizes **reflective practice** as a way to consolidate learning (Schön, 1983). In CEL, feedback can be text-based, rubric-based, or delivered in follow-up virtual sessions, with stored results allowing for ongoing review.

2.4 Challenges in Online and Cloud-Enabled Learning

Despite the promise of CEL and progressive models, challenges persist. Studies highlight:

- The **digital divide** — unequal access to devices and stable internet [16].
- **Instructor readiness** — need for continuous professional development in cloud tools (Al-Rwaidan et al., 2023).
- **Infrastructure dependence** — reliance on high-speed, reliable networks (Kyriakou et al., 2023).

Addressing these challenges requires adaptable deployment strategies, such as tiered infrastructure setups, device lending programs, and hybrid delivery models.

2.5 Research Gap

While prior studies have explored cloud-enabled labs or progressive pedagogies independently, few have **integrated both into a structured, multi-phase model** and tested its impact in real classrooms. This study addresses that gap by piloting the **Five-Phase CE-PL model** in a real-world undergraduate setting, measuring its effect on learning outcomes, and assessing its potential for scalability.

III. Methodology

3.1 Research Design

This study adopts a **quasi-experimental, pre-test/post-test control group design** to evaluate the short-term impact of the Five-Phase Cloud Enabled Progressive Learning (CE-PL) model on student performance. While random assignment was not feasible due to class scheduling constraints, groups were selected to be comparable in academic background and prior exposure to computer science courses.

As a **pilot study**, the primary goal was to establish preliminary evidence of feasibility and effectiveness before conducting larger-scale, randomized trials.

3.2 Participants

The study was conducted with **90 undergraduate students** enrolled in the Bachelor of Computer Applications (BCA) program at *[Institution Name]*. Participants were drawn from first-year, second-year, and third-year cohorts to ensure diversity in academic experience.

- **Control Group:** 45 students taught using traditional lecture–lab methods in a fixed computer laboratory setting.
- **Experimental Group:** 45 students taught using the CE-PL model within a Cloud Enabled Laboratory (CEL).

Table 2 summarizes participant demographics.

Table 2: Participant Demographics

Cohort	Control Group (n=45)	Experimental Group (n=45)
BCA 1st Year	15	15
BCA 2nd Year	15	15
BCA 3rd Year	15	15

3.3 The Five-Phase CE-PL Intervention

The experimental group engaged in the Five-Phase Progressive Learning cycle over the course of one semester:

1. **Planning & Scheduling** – Students received access to a pre-configured virtual machine (VM) schedule and learning plan.
2. **Learning Approach** – Live demonstrations and guided practice conducted via CEL shared screens.
3. **Collaboration & Discussion** – Group problem-solving activities in CEL forums and virtual workspaces.
4. **Assessment & Outcome** – Submission of assignments and lab tasks through the CEL platform.
5. **Feedback & Review** – Instructor and peer feedback provided through CEL forums and follow-up sessions.

The control group covered the same curriculum but followed traditional methods: in-person lectures, fixed lab hours, and physical access to institution-owned desktops.

3.4 Instruments and Data Collection

Two primary instruments were used to assess learning outcomes:

- **Pre-Test:** Administered before the intervention to assess baseline knowledge of topics such as Linux, Web Designing, C Programming, and Office Tools.
- **Post-Test:** Administered at the end of the semester to measure knowledge gain.

Both tests consisted of 30 multiple-choice and short-answer questions designed to evaluate conceptual understanding, problem-solving ability, and applied skills.

In addition, **CEL usage logs** (for the experimental group) recorded:

- Number of VM logins
- Duration of sessions
- Forum participation rates

3.5 Statistical Analysis
Data were analyzed using:
- **Descriptive statistics** (Mean, Median, Standard Deviation) to summarize scores.
- **Independent samples t-test** to compare mean scores between control and experimental groups at both pre-test and post-test stages.
- **p-values** calculated at a 0.05 significance level to determine statistical significance.

3.6 Ethical Considerations
All participants provided informed consent prior to the study. Students were assured that participation would not affect their grades and that all results would be anonymized for reporting purposes. Institutional approval was obtained for the use of CEL in classroom instruction.

IV. Results

4.1 Pre-Test Analysis
Before the intervention, both the control and experimental groups completed a **pre-test** to assess their baseline knowledge. Table 3 summarizes the results.

Table 3: Pre-Test Scores – Control vs. Experimental Group

Group	n	Mean	SD	t-value	p-value
Control	45	22.09	6.43	0.9363	0.3516
Experimental	45	23.39	6.74		

Interpretation:
The mean scores were close (difference of 1.30), and the p-value (0.3516) exceeded the significance threshold of 0.05. This indicates **no statistically significant difference** in prior knowledge between the two groups. The groups were therefore reasonably equivalent at the start of the semester.

4.2 Post-Test Analysis
At the end of the semester, a **post-test** was conducted to evaluate knowledge gains.

Table 3: Post-Test Scores – Control vs. Experimental Group

Group	n	Mean	SD	t-value	p-value
Control	45	23.71	5.82	4.85	0.0001***
Experimental	45	28.94	4.98		

Interpretation:
The experimental group's mean score (28.94) was **5.23 points higher** than the control group's mean (23.71). The p-value (< 0.0001) indicates this difference is **highly statistically significant**, suggesting that the CE-PL model had a substantial positive effect on student performance in this pilot study.

4.3 CEL Usage Patterns (Experimental Group Only)
System logs from the CEL platform revealed notable engagement patterns:
- Average **VM logins per student per week**: 4.2
- Average **session duration**: 46 minutes
- Average **forum participation rate**: 73% of students posted at least once per week

Interpretation:
High engagement levels suggest that students took advantage of the **anytime, anywhere access** provided by CEL. Forum participation rates indicate that collaborative elements were well-utilized, although future studies could investigate strategies to increase participation closer to 100%.

4.4 Summary of Findings
1. **Baseline Equivalence:** No significant difference in pre-test scores confirms the groups were comparable at the start.
2. **Learning Gains:** Significant post-test improvement in the experimental group demonstrates the effectiveness of the CE-PL model.

3. **Student Engagement:** Usage patterns indicate active and regular participation, aligning with progressive learning principles.

V. Discussion and Implications

5.1 Interpreting the Findings

The results of this pilot study demonstrate that the **Five-Phase Cloud Enabled Progressive Learning (CE-PL) model** significantly improved student performance compared to traditional lecture–lab instruction. The statistically significant post-test gains in the experimental group suggest that a structured, cloud-enabled, and student-centered approach enhances both **conceptual understanding** and **practical application skills**.

The engagement data further supports this conclusion. High rates of CEL logins and forum activity indicate that students were not only accessing resources but actively participating in collaborative learning activities. This aligns with constructivist and progressive theories, which emphasize that learning is most effective when it is **interactive, participatory, and contextualized** (Dewey, 1938; Vygotsky, 1978).

5.2 Pedagogical Implications

1. **Enhanced Accessibility**

CEL's virtual infrastructure allowed students to extend their lab practice beyond scheduled hours, addressing the time constraints of traditional laboratories. This aligns with findings from [16] on the importance of flexible access in sustaining engagement.

2. **Integration of Collaboration and Feedback**

The structured "Collaboration & Discussion" and "Feedback & Review" phases facilitated ongoing peer-to-peer and instructor-student interaction, which literature suggests can deepen understanding and promote retention [13].

3. **Alignment with Industry Practices**

By simulating real-world development environments and tools within the CEL, the CE-PL model mirrors the collaborative workflows students are likely to encounter in professional settings.

5.3 Institutional Implications

1. **Scalability Potential**

Although this pilot was limited to 90 students at one institution, the CEL infrastructure is inherently scalable. Cloud hosting and virtualized environments can be adapted for larger cohorts with minimal physical expansion costs.

2. **Cost Considerations**

While initial setup requires investment in server infrastructure and training, the long-term operational costs can be lower than maintaining physical labs, particularly in terms of hardware replacement cycles and staffing.

3. **Equity and Inclusion**

The model holds potential for bridging the digital divide if combined with institutional policies to provide loaner devices or subsidized internet access, ensuring all students benefit equally.

5.4 Limitations of the Pilot Study

While results are promising, several limitations must be acknowledged:

- **Non-randomized group assignment**: Although baseline equivalence was established, selection bias cannot be fully ruled out.
- **Single-institution scope**: Findings may not generalize to other contexts without replication.
- **Short-term measurement**: Outcomes were assessed immediately post-intervention; long-term retention was not evaluated.
- **Infrastructure dependence**: The model's success relies on stable internet and server uptime, which may vary across regions.

5.5 Directions for Future Research

To build on these findings, future work should:

1. **Conduct multi-institution randomized controlled trials** to validate results across diverse educational contexts.
2. **Include longitudinal tracking** of students to assess knowledge retention and skill transfer into real-world applications.
3. **Integrate learning analytics** (e.g., AI-powered dashboards) for adaptive feedback, aligning with recent advances in personalized education [17].
4. **Evaluate cost-effectiveness** by comparing CEL deployment and maintenance costs against traditional lab operation over several years.

5. **Expand to other disciplines** such as engineering, health sciences, or business, to test the framework's versatility.

VI. Conclusion

This pilot study evaluated the impact of a Five-Phase Cloud Enabled Progressive Learning (CE-PL) model on student performance in undergraduate computer science courses. The model, implemented through a Cloud Enabled Laboratory (CEL), integrates progressive and constructivist pedagogical principles with cloud-based infrastructure to create a flexible, accessible, and collaborative learning environment.

Findings from the comparison between the experimental and control groups indicate that CE-PL significantly improved learning outcomes within a single semester. The structured learning phases — Planning & Scheduling, Learning Approach, Collaboration & Discussion, Assessment & Outcome, and Feedback & Review — ensured that students progressed through a full cycle of knowledge acquisition, application, and reflection. High levels of CEL engagement further suggest that the model encouraged active participation beyond the constraints of traditional laboratory sessions.

While the scope of this study was intentionally limited to 90 students at one institution, the results point toward a scalable approach that can address common challenges in ICT education, including restricted access to physical labs, limited collaboration opportunities, and uneven distribution of resources. Importantly, the CE-PL model does not aim to replace traditional teaching entirely but rather to supplement and enhance it, providing institutions with a flexible pathway toward blended and online delivery models.

Given the encouraging results, future research should expand the study across multiple institutions and disciplines, employ randomized controlled designs, and examine long-term retention and skill transfer. By doing so, the CE-PL model can be rigorously validated and refined, ensuring its readiness for broad adoption in higher education.

In an era where technological change demands equally dynamic teaching strategies, this pilot demonstrates that combining pedagogical structure with cloud-enabled flexibility can deliver measurable improvements in learning — and hold the potential to reshape how practical computing education is delivered worldwide.

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