Exploring Advanced Pedagogies for Engineering Educators: Active Learning Strategies and ICT-Based Digital Tools

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ABSTRACT

Pedagogy denotes the theory and practice of teaching — the methods, strategies, and approaches through which knowledge, skills, and values are transferred between educators and learners. Contemporary classrooms increasingly integrate information and communication technology (ICT) with active-learning strategies to improve student engagement, motivation, and outcome attainment. This paper examines advanced pedagogical approaches, including teacher-centred versus student-centred instruction and high-technology versus low-technology delivery, and evaluates five widely adopted ICT tools and strategies — Kahoot, Gallery Walk, Moodle, Think-Pair-Share, and virtual-classroom platforms such as Zoom and Google Meet — that support collaborative and self-directed learning. A case implementation is reported for the undergraduate course "Big Data Architecture and Tools" (1152CS229), in which these strategies were embedded across a semester and mapped to program outcomes (POs) and student outcomes (SOs) under Washington Accord–aligned accreditation criteria. Course outcome (CO) attainment was assessed using internal assessment records — quizzes, assignments, and a Test/Discussion/Interaction activity — delivered through a Moodle-based platform, supplemented by an end-of-course student feedback survey. Results indicate consistently high attainment: four of five course outcomes reached 90% attainment (attainment level 2.7 of 3), and one reached 86.7% (level 2.6), both exceeding the institutional 70% threshold. CO-PO and CO-SO correlation mapping further confirmed moderate-to-strong alignment with graduate-attribute requirements. The findings suggest that combining active-learning techniques with digital tools can measurably improve course outcome attainment, while highlighting persistent implementation challenges such as time constraints, resource limitations, and the need to balance diverse learner needs.

Keywords: Pedagogy; Active Learning; ICT Tools; Course Outcome Attainment; Moodle; Kahoot; Outcome-Based Education.

1. Introduction

Pedagogy, in its broadest sense, refers to the theory and practice of teaching: the methods, strategies, and approaches through which educators facilitate the transfer of knowledge and the development of skills in learners. Beyond the act of instruction itself, pedagogy encompasses the design of learning environments, the interaction between teachers and students, and the continuous evaluation of teaching effectiveness [1]. While discussions of pedagogy often focus narrowly on instructional technique, effective teaching is equally concerned with student learning outcomes, classroom management, and the alignment of content delivery with learner needs.

The proliferation of information and communication technology (ICT) has reshaped how content is delivered and how student engagement is measured. Learning management systems such as Moodle, game-based assessment platforms such as Kahoot, and video-conferencing tools such as Zoom and Google Meet have become integral to blended and distance-learning environments [2]. These tools extend the classroom beyond its physical boundaries and provide instructors with more immediate feedback on learner performance than traditional methods allow.

This paper examines advanced pedagogical strategies and the digital tools that support them, with two aims. First, it reviews the theoretical classification of teaching approaches — teacher-centred versus student-centred, and high-technology versus low-technology — together with five commonly adopted ICT tools. Second, it reports a case implementation in an undergraduate engineering course, in which these strategies were embedded across a semester and evaluated against course outcome (CO), program outcome (PO), and student outcome (SO) attainment criteria used for outcome-based accreditation. The remainder of the paper is organised as follows: Section 2 reviews related literature; Section 3 outlines the theoretical framework of teaching approaches; Section 4 describes the methodology; Section 5 presents the ICT tools and active-learning strategies used; Section 6 reports the results and discussion of outcome attainment; Section 7 discusses implementation challenges; and Section 8 concludes the paper.

2. Literature Review

Research on twenty-first-century learning consistently identifies digital literacy, collaboration, and critical thinking as core competencies that pedagogy must cultivate [1]. Coccoli et al. [2] describe the transition toward "smarter universities," arguing that higher-education institutions must adapt their infrastructure and teaching models to a fast-changing digital era. Related work on smart learning environments frames technology-enhanced pedagogy as context-aware and ubiquitous, extending learning beyond the physical classroom through mobile and cloud-based platforms [3]. Tikhomirov et al. [4] further characterise smart education along three dimensions — environment, pedagogy, and technology — suggesting that effective digital pedagogy requires alignment across all three.

Augmented and virtual reality have also been explored as tools for immersive, collaborative learning, particularly for demonstrating procedures that are difficult to replicate in a physical laboratory [5]. On the assessment side, formative assessment supported by learning analytics has been shown to give instructors continuous, data-driven insight into student progress, enabling timely intervention [6]. In the specific context of engineering education, Villanueva et al. [7] surveyed teaching-evaluation practices across accredited programs and found considerable variation in how course outcomes are measured and reported, underscoring the need for standardised, outcome-based evaluation frameworks such as the one adopted in this study.

Collectively, this literature supports two premises that motivate the present work: first, that digital tools meaningfully extend the reach and responsiveness of pedagogy; and second, that rigorous, outcome-based measurement is necessary to demonstrate their effectiveness rather than relying on anecdotal evidence.

3. Theoretical Framework: Teaching Approaches

Teaching approaches can be classified along two broad, partly overlapping dimensions, illustrated in Figure 1: the degree of instructor versus learner control (teacher-centred vs. student-centred) and the extent of technology integration (high-tech vs. low-tech).

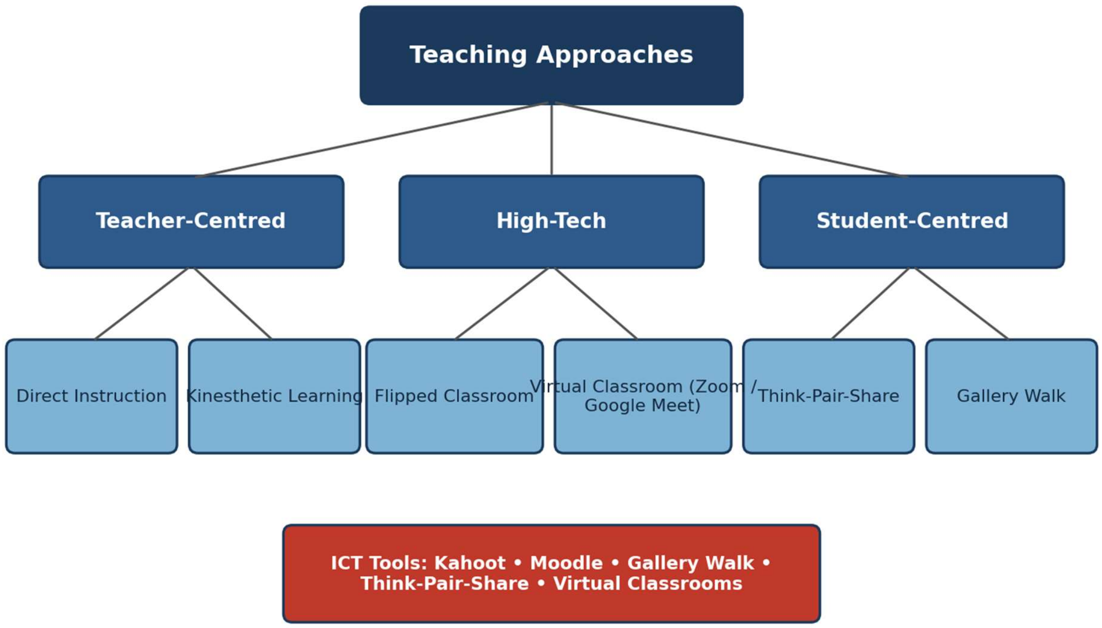


Figure 1. Taxonomy of teaching approaches and associated ICT tools.

3.1 High-Tech and Low-Tech Approaches

Advances in classroom technology over the past two decades have expanded the range of methodologies available to support student learning [3]. Many instructors now supplement lectures with online resources, giving access to a wide range of learning material and enabling instruction for geographically dispersed learners. Nonetheless, low-technology approaches retain pedagogical value: some learning styles depend on direct peer-to-peer communication, and handwritten note-taking is preferred by some students, even though it places greater demand on spelling and writing proficiency.

3.2 Teacher-Centred and Student-Centred Methods

Under direct instruction — a teacher-centred, typically low-tech method — the instructor delivers structured lectures and demonstrations following a defined lesson plan, positioning the teacher as the primary source of knowledge and skill. Kinesthetic approaches, by contrast, engage students through movement, gesture, and hands-on demonstration; certain skills, such as laboratory technique, are difficult to teach through observation alone. High-tech, student-centred environments use digital platforms, interactive software, and virtual or augmented reality to create personalised learning experiences that engage students directly with course content. The flipped classroom, first popularised in 2007, exemplifies this shift: students review pre-recorded lecture material independently and use class time for applied, collaborative activities, reversing the traditional lecture-then-homework sequence.

4. Methodology

This study adopts a case-implementation design situated within a single undergraduate engineering course. Active-learning strategies and ICT tools were embedded throughout the delivery of the course 1152CS229 — Big Data Architecture and Tools — during the 2019–2020 academic year. The course covers foundational data-science and big-data-analytics concepts, including data-processing paradigms, the Hadoop/HIVE ecosystem, distributed computing with MongoDB, data analysis using R and Octoparse, and stream processing with Spark RDD.

4.1 Course Outcomes and Outcome Alignment

Five course outcomes (CO1–CO5) were defined and mapped to Bloom's revised taxonomy knowledge and skill levels, as summarised in Table 1. Each course outcome was subsequently correlated with the program outcomes (POs) and student outcomes (SOs) required under Washington Accord–aligned accreditation criteria (Table 2), using a three-point scale (1 = low, 2 = medium, 3 = high correlation).

Table 1. Course outcomes and Bloom's taxonomy mapping.

CO No.	Course Outcome	Knowledge Level*
CO1	Differentiate traditional data processing with Big Data Analytics.	K2, S3
CO2	Describe the technology landscape behind Big Data Analytics using Hadoop and HIVE.	K3, S3
CO3	Solve distributed computing challenges with the help of MongoDB.	K3, S3
CO4	Perform data analysis using R and Octoparse.	K3, S3
CO5	Perform essential operations for data sharing using Spark RDD.	K3, S3

4.2 Data Collection

Course outcome attainment was measured from internal assessment records — quizzes, assignments, and a Test/Discussion/Interaction (TDI) activity ("Flash Fill") — administered through the Moodle-based platform Vlearn. An anonymous, end-of-course survey was additionally distributed to enrolled students to capture their perceived effectiveness of the course, categorised into three levels (Average, Good, Excellent). Attainment percentages and attainment levels reported in Section 6 were computed from these internal assessment records.

5. ICT Tools and Active-Learning Strategies

In addition to conventional instruction, five ICT-enabled tools and strategies were used to promote collaboration and self-directed learning, summarised below.

5.1 Kahoot

Kahoot is a game-based learning platform, launched in September 2013 by Morten Versvik, Johan Brand, and Jamie Brooker in collaboration with the Norwegian University of Science and Technology, and accessible via a web browser or dedicated application. Instructors design quiz-style questions that students answer in real time, converting assessment into a competitive, decision-based activity that increases engagement.

5.2 Gallery Walk

Gallery Walk is a classroom-based active-learning technique that promotes higher-order thinking through collaborative discussion. The instructor prepares a set of discussion questions, which are posted around the classroom on paper or chart boards; students, typically working in groups of three to five, rotate between stations to respond. Questions may test recall and comprehension or probe higher-order skills such as analysis, synthesis, and evaluation.

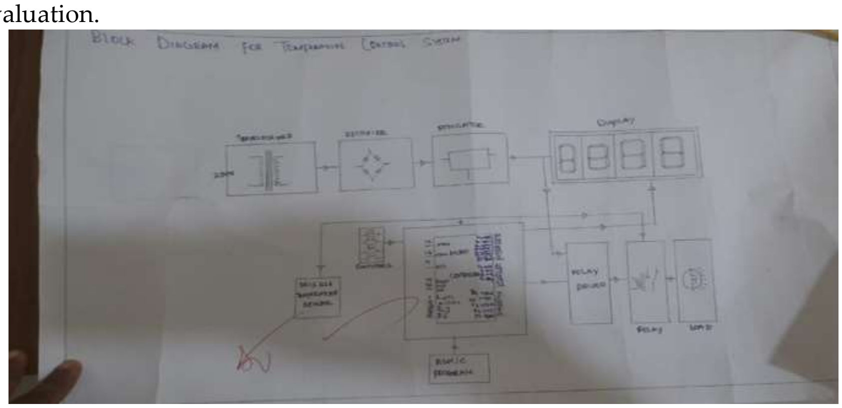


Figure 2. Gallery Walk activity conducted with students.

5.3 Moodle

Moodle is a free, open-source learning-management platform first released in August 2002, with continued updates (most recently referenced here as of May 2020). It supports blended learning, distance education, and flipped-classroom delivery through a wide library of plugins and themes, including MATLAB coding-problem modules, SCORM packages, Turnitin assignment integration, WebEx meeting integration, interactive content, and BigBlueButton video conferencing. Its principal role in this implementation was to streamline the creation, distribution, and grading of assignments in a paperless format.

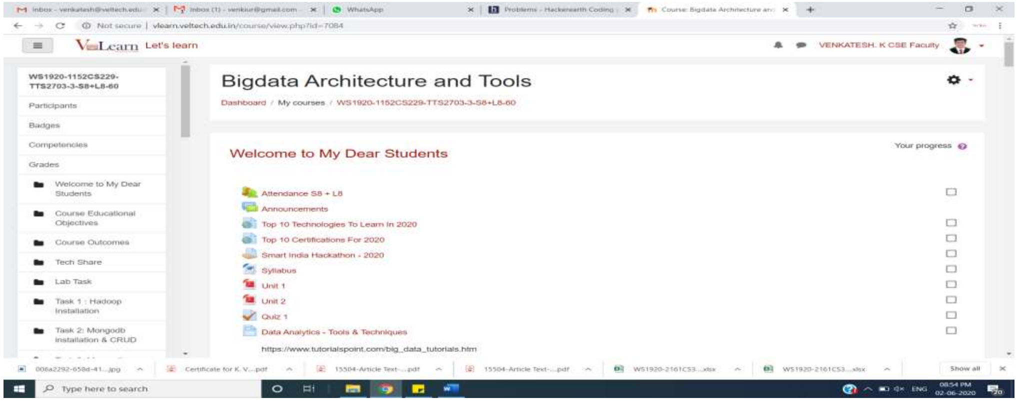


Figure 3. Course activity dashboard on the Moodle-based Vlearn platform.

5.4 Think-Pair-Share (TPS)

Think-Pair-Share is a collaborative learning strategy in which students first consider a problem individually (Think), form small teams of three or four (Pair), and then present their reasoning to the group and, subsequently, the whole class (Share). The strategy develops both critical-thinking capability and oral-communication skill, and can be combined with any of the ICT tools described above.

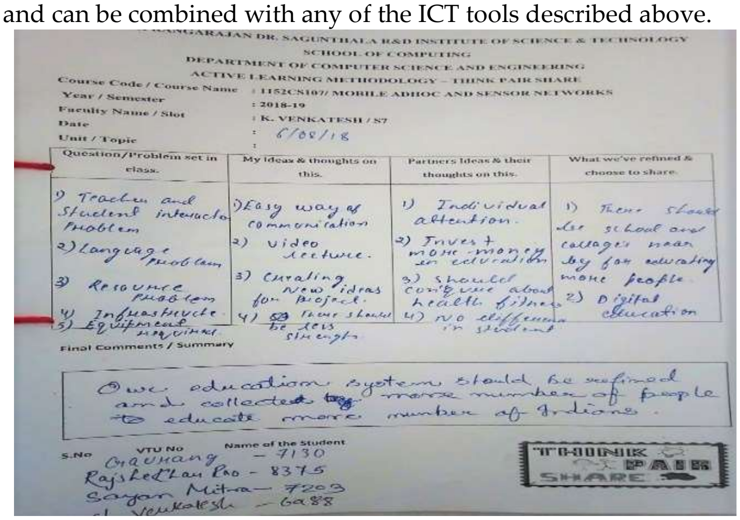


Figure 4. Think-Pair-Share activity in progress.

5.5 Virtual Classroom

A virtual classroom is a shared online environment that enables live, simultaneous interaction between students and faculty, whether used independently or alongside conventional classroom activities. It supports brainstorming, group discussion, questionnaire sessions, and hands-on demonstration, with pre- and post-session assessment. Representative platforms include Zoom, Google Meet, Veyon, Edmodo, Eliademy, TeacherEase, and Insight.

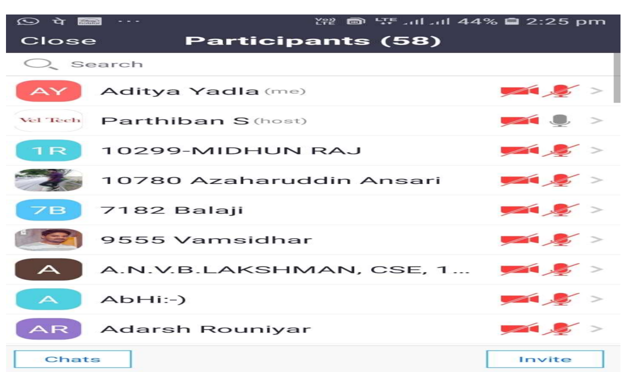


Figure 5. Student participation recorded during a virtual classroom session (Zoom).

6. Results and Discussion

6.1 Course Outcome Attainment

Table 2 and Figure 6 present the course outcome (CO) attainment for 1152CS229, derived from internal assessment records. Four of the five course outcomes (CO1, CO2, CO4, CO5) achieved an attainment level of 2.7 out of 3 (90.0%), while CO3 achieved a level of 2.6 (86.7%). All five outcomes exceeded the institutional minimum attainment threshold of 70%, indicating that the combination of direct instruction, Moodle-based assessment, and active-learning activities was effective in achieving the intended learning outcomes for this course.

Table 2. Course outcome attainment level and percentage.

Course Outcome	Attainment Level (of 3)	Attainment (%)
CO1	2.7	90.0%
CO2	2.7	90.0%
CO3	2.6	86.7%
CO4	2.7	90.0%
CO5	2.7	90.0%

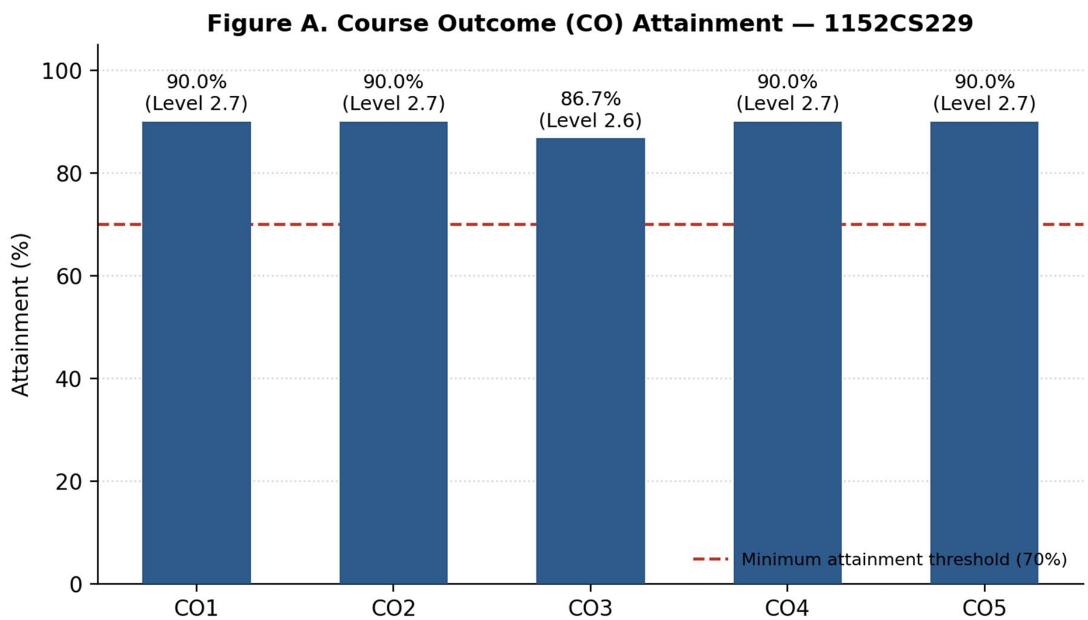


Figure 6. Course outcome (CO) attainment for 1152CS229.

The comparatively lower attainment for CO3 (distributed computing with MongoDB) suggests that this topic was relatively more challenging for students, possibly owing to its greater technical complexity relative to the other outcomes; this observation is consistent with informal classroom feedback and points to an area for additional scaffolding in future course offerings.

6.2 CO-PO and CO-SO Correlation Mapping

Table 3 and Figure 7 present the correlation between the course and the program outcomes (POs) required under NBA accreditation criteria. The course showed a medium correlation (level 2) with PO2, PO4, and PO9 — which relate to problem analysis, modern-tool usage, and individual/teamwork skills — and a low correlation (level 1) with PO1, PO3, and PO5, which are more directly addressed by other courses in the curriculum.

Table 3. Course-to-Program-Outcome (CO-PO) correlation matrix.

PO1	PO2	PO3	PO4	PO5	PO9	PO12
1	2	1	2	1	2	2

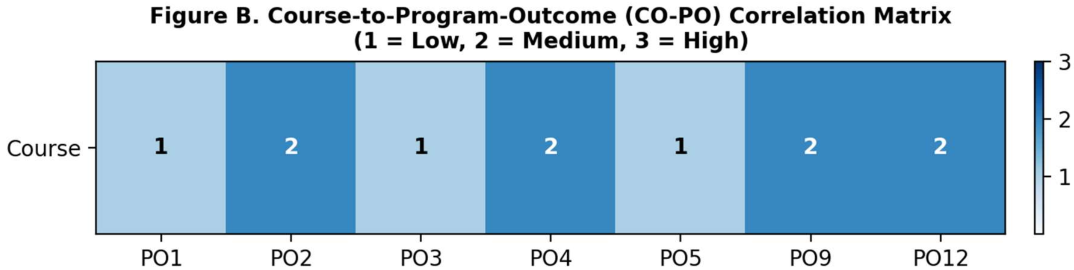


Figure 7. Course-to-Program-Outcome (CO-PO) correlation matrix.

Figure 8 similarly maps the course to student outcomes (SOs) under both EAC and CAC accreditation criteria. The pattern is broadly consistent across both frameworks, with the strongest correlations observed for SO1, SO2, SO6, and SO7 — outcomes associated with technical problem-solving and the use of modern computing tools — reflecting the hands-on, tool-based nature of the course content.

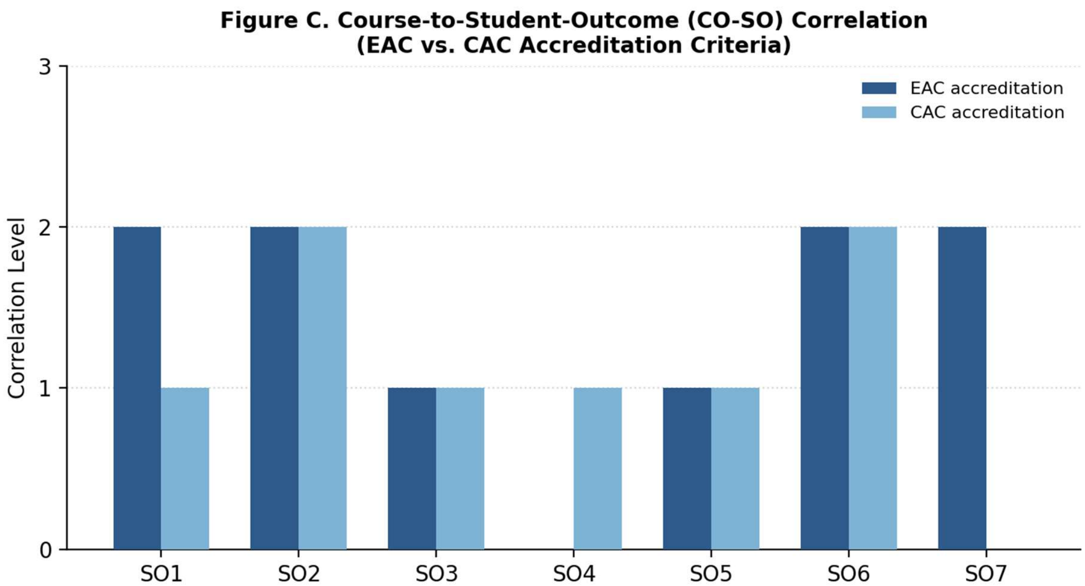
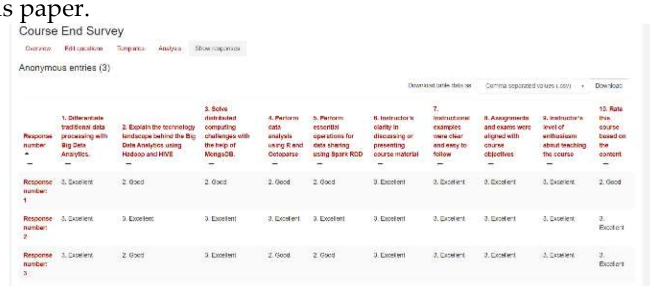


Figure 8. Course-to-Student-Outcome (CO-SO) correlation, EAC vs. CAC accreditation criteria.

6.3 Student Feedback

An anonymous, end-of-course survey (Figure 9) was distributed to all enrolled students to assess the perceived effectiveness of the course, with responses categorised into three levels: Average, Good, and Excellent. This qualitative feedback complemented the quantitative attainment data reported above and is intended to inform iterative refinement of the course in subsequent offerings; detailed response-level data were not retained for statistical reporting in this paper.



Course End Survey

Anonymous entries (3)

Response number	1. Differentiate traditional data processing with Big Data Analytics.	2. Explain the technology landscape behind the Big Data Analytics using Hadoop and HIVE	3. Solve distributed computing challenges with the help of MongoDB.	4. Perform data analysis using R and Octoparse	5. Perform essential operations for data sharing using Spark RDD	6. Instructor's clarity in discussing or presenting course material	7. Instructional examples were clear and easy to follow	8. Assignments and exams were aligned with course objectives	9. Instructor's level of enthusiasm about teaching the course	10. Rate this course based on the content.
Response number: 1	3. Excellent	2. Good	2. Good	2. Good	2. Good	3. Excellent	3. Excellent	3. Excellent	3. Excellent	2. Good
Response number: 2	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent
Response number: 3	3. Excellent	2. Good	3. Excellent	2. Good	2. Good	3. Excellent	3. Excellent	3. Excellent	3. Excellent	3. Excellent

Figure 9. Course-end survey instrument distributed to students.

Representative learning artefacts and platform screenshots from the implementation are provided in Figures 10–12, showing the shared course-materials repository, the Flash Fill TDI activity, and the online quiz interface used for formative assessment.

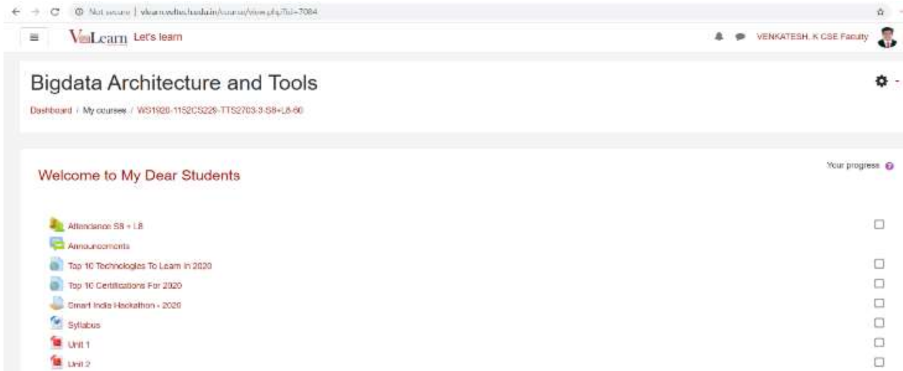


Figure 10. Shared course-materials repository accessible to students.

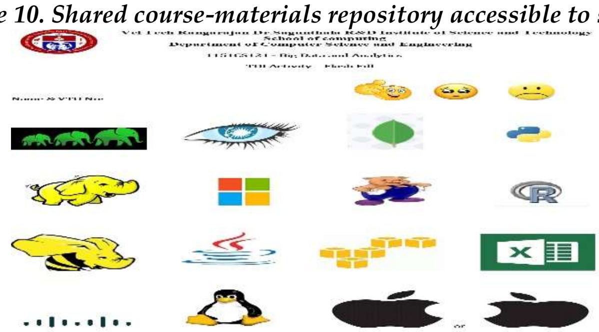


Figure 11. Flash Fill Test/Discussion/Interaction (TDI) activity.

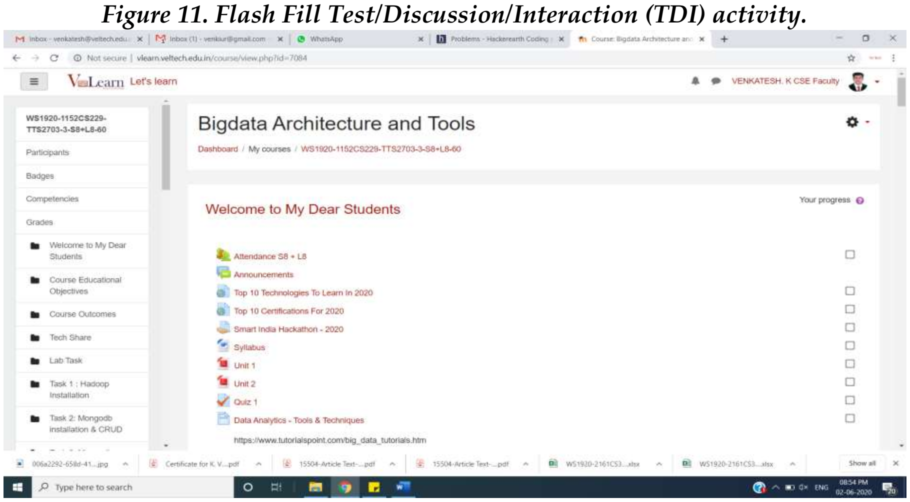


Figure 12. Online quiz interface used for formative assessment.

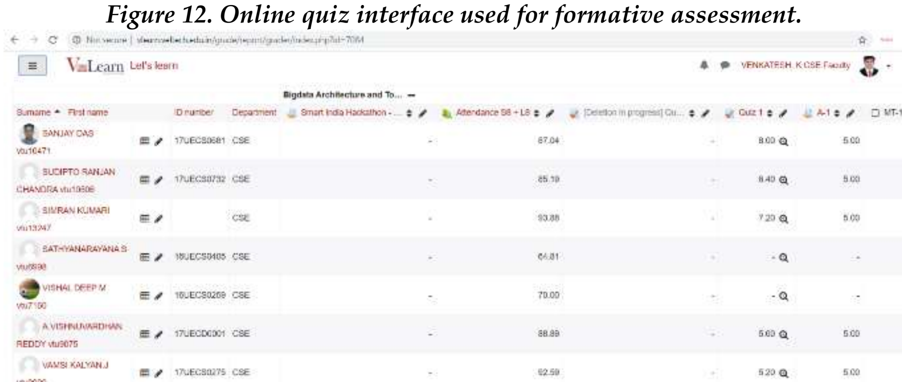


Figure 13. Assessment-overview dashboard showing internal marks.

7. Challenges

Implementation of the strategies described above surfaced several practical challenges, consistent with those reported elsewhere in the active-learning literature:

- Balancing the diverse learning needs of individual students within a single class format.
- Limited time available for the additional planning that active-learning activities require.

- Constraints on institutional resources, including devices and reliable internet access.
- Increased administrative and paperwork burden associated with data collection for outcome-based reporting.
- Accountability expectations placed on instructors that extend beyond direct teaching responsibilities.
- A tendency for all students to be assessed against a uniform curriculum pace, irrespective of individual readiness.

Careful selection and sequencing of ICT tools, together with institutional support for training and infrastructure, can mitigate several of these challenges and help sustain the outcome levels reported in Section 6.

8. Conclusion

This paper examined advanced pedagogical approaches and ICT-based digital tools, situating them within a theoretical framework spanning teacher-centred versus student-centred and high-tech versus low-tech dimensions of instruction. A case implementation in the course 1152CS229 demonstrated that combining direct instruction with active-learning strategies — Kahoot, Gallery Walk, Moodle, Think-Pair-Share, and virtual-classroom sessions — achieved course outcome attainment of 86.7–90.0% across all five defined outcomes, exceeding the institutional 70% threshold, with correlation mapping confirming reasonable alignment to required program and student outcomes. These results suggest that a deliberately blended pedagogical approach, supported by systematic outcome measurement, can produce measurable gains in student learning while remaining responsive to the practical constraints instructors face. Future work should extend this evaluation across multiple course offerings and cohorts to test the generalisability of these findings, and should incorporate quantitative analysis of the end-of-course survey responses to more directly link specific ICT tools to perceived learning gains.

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