CIPHER: An AI-Driven Gamified Activity Model for Enhancing Learning and Engagement in Engineering Education

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***Abstract*—In response to the growing need for active and engaging learning environments in engineering education, this study introduces CIPHER—a five-layered gamification framework enhanced with AI-driven personalization. Implemented in the first year Digital Systems course, the model—Create, Involve, Predict & Hide, Engage, Reflect (CIPHER)—transformed conventional classroom delivery into a collaborative logic-based decoding challenge. Results from a controlled experiment revealed a statistically significant improvement in student performance, with the experimental group (CIPHER-enabled) achieving higher average Continuous Assessment Test scores confirmed using independent samples T-test ($t = 10.49$, $p < 0.001$) than the control group. A post-activity Likert-scale survey (mean scores >4.3) indicated enhanced student engagement, stronger teamwork, and development of higher-order thinking skills. The AI-generated questions used in the Create layer received positive feedback from both students and faculty experts for their alignment with course outcomes and academic rigor. The model's successful implementation in other disciplines further confirms its scalability and adaptability. Recognized with a Best Strategy Award at a Faculty Conclave, CIPHER offers a replicable, low-cost approach to blending AI, gamification, and collaborative learning for improved outcomes in technical and interdisciplinary education.**

***Keywords*—Gamification, Artificial Intelligence, Collaborative Learning, Engineering Education, CIPHER Model, Digital System Course**

I. INTRODUCTION

In a typical engineering classroom, students often find themselves surrounded by complex logic diagrams, truth tables, and sequential circuits. Though intellectually capable, many of them feel disconnected not due to a lack of curiosity, but because traditional teaching methods seldom speak their language. What begins with enthusiasm gradually shifts into a cycle of notes taking, memorization, and performance under pressure. For faculty, the challenge isn't just in delivering content but in keeping curiosity alive amidst heavy syllabi and exam driven expectations. In this climate, the idea of making learning more engaging has become more urgent than ever.

One promising approach that has gained momentum is gamification the use of game like elements such as points, levels, badges, leaderboards and challenges in non-game environments like education. The intent isn't to trivialize learning, but to borrow what makes games so gripping, motivation, progress tracking, and a sense of achievement. After all, if games can keep individuals immersed for hours, couldn't the same psychology help students stay involved in classrooms?

Research in recent years supports this idea. For example, Kaur et al. (2023) observed significant improvements in classroom energy and retention when game mechanics were embedded into lessons. Tools such as Kahoot!, Quizizz, and Moodle's gamification plugins have gained widespread popularity, especially in making assessments feel more interactive and less intimidating. However, while these tools work well for quick-response quizzes or trivia-style reviews, they often struggle to adapt to technical subjects like Digital Systems where the ability to decode binary logic, troubleshoot combinational circuits, and understand finite state machines is key. Here in the first crack most gamification models focus primarily on surface level engagement through Points, Badges, and Leaderboards (PBL). While these can reward fast recall, they do little to encourage higher order thinking such as problem decomposition, systems analysis, and design reasoning. As a result, many students may enjoy the activity but walk away with limited conceptual depth.

The second limitation lies in integration. Gamified activities are often treated as standalone events interesting but peripheral to the course objectives. According to Sharma and Yadav (2023), this disconnect reduces the long-term impact of gamification, as it isn't deeply woven into the structure of course learning outcomes (CLOs). Thirdly, AI-driven personalization though revolutionizing platforms in fields like coding and language learning has barely touched gamified engineering education. Current systems often reuse

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the same static questions across cohorts, with little scope for adaptive learning paths.

Finally, existing gamification literature is often anecdotal or based on small feedback surveys. Few studies implement controlled, comparative experiments to measure actual learning gains. There's a visible lack of mixed-method validation both quantitative (scores) and qualitative (student reflections) to demonstrate meaningful impact over traditional teaching models. In this research, a novel gamification model called "CIPHER" model is proposed for in-class activity. Recent research in AI-supported adaptive learning and automated assessment systems (e.g., Culbida, C et al, 2025) further emphasizes the importance of integrating AI-generated content into pedagogically structured frameworks. These studies support the need for personalized, scalable, and automated learning workflows that informed the design of the CIPHER model.

II. RESEARCH QUESTIONS

With the above literature study, the following research questions (ReQu) have been formulated for the research.

RQ1: What is the impact of the CIPHER gamification model on student's academic performance compared to traditional instructional methods?

RQ2: How does the CIPHER model influence student's collaborative learning processes and development of higher order thinking skills during problem-solving activities?

RQ3a: What are student's perceptions of the CIPHER model in terms of its instructional clarity, learning experience and overall classroom experience?

RQ3b: How effective is the integration of AI-generated, instructor-curated questions (Layer 1: Create) in supporting outcome-based learning?

RQ3c: How do the five progressive layers of CIPHER (Create, involve, Predict & Hide, Engage, Reflect) foster teamwork and reflective learning behaviours among students?

III. PROPOSED GAMIFICATION

To transform passive content delivery into an active, engaging, and collaborative learning experience, a gamified instructional intervention was conceptualized specifically for the Digital Systems course. This intervention was built upon a custom-developed pedagogical gamification framework titled CIPHER, which stands for Create, Involve, Predict & Hide, Engage, and Reflect. The model was designed to align with course outcomes while promoting higher-order thinking and peer-to-peer learning. The Figure 1 shows the details of the proposed model.

The CIPHER model is a structured gamification framework designed to create engaging, collaborative, and goal-oriented learning experiences. The CIPHER model was not just a framework but the backbone of our classroom activity, seamlessly guiding each phase from designing tasks to fostering collaboration and reward driven engagement. Each layer of CIPHER shall be mapped onto our implementation directly, transforming theory into a dynamic learning experience, It consists of five layers:

Layer 1 – C: Create

Instructors generate or curate learning tasks aligned to course outcomes. Tasks are designed to be challenging yet achievable, ensuring they stimulate problem-solving and critical thinking. AI tools (e.g., ChatGPT) can be used for question generation, with manual refinement to ensure academic quality.

Layer 2 – I: Involve

Learners are grouped strategically to ensure balanced team compositions. Roles within teams can be assigned to encourage participation, accountability, and collaboration. The activity goal is communicated clearly, motivating students to contribute to a collective outcome.

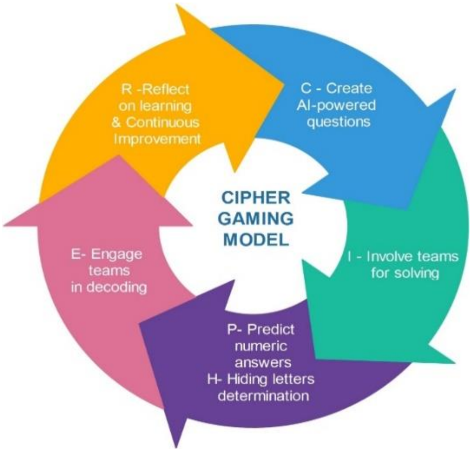

Fig. 1. The CIPHER Model

Layer 3 – P & H: Predict & Hide

Teams work on solving their assigned tasks, where each correct response contributes to a hidden or partially concealed final outcome. The "hidden" element creates suspense and ensures focus, as the final objective depends on all teams' accuracy.

Layer 4 – E: Engage

Once partial results are obtained, teams collaborate to assemble the complete solution. This phase fosters inter-team interaction, peer verification, and mutual support. The collective goal ensures that accuracy from every group is essential for overall success.

Layer 5 – R: Reflect

Teams and instructors review the process, identify areas for improvement, and consolidate conceptual learning. Feedback loops can be used to enhance future iterations of the activity.

The CIPHER model is adaptable to different subjects, class sizes, and delivery modes, making it a versatile tool for gamified, active learning.

The design flow in the model is shown in Figure 2. The following section presents how the CIPHER model was implemented in the classroom for Digital System course. The course is offered from XYZ college of Engineering to the first year Electrical students. This design forced precision, encouraged peer review, and emphasized team responsibility and inter-team collaboration.

Sample Implementation: Digital Systems Course

Game Objective: Each team in Class A was given eight binary logic questions. The learning objective of the activity is to apply knowledge in order to deepen understanding of combinational circuits and their design. Upon solving these, the binary answers (0s and 1s) were combined to form an 8-bit binary number, which was then converted to its decimal equivalent and finally mapped to an ASCII (American Standard Code for Information Interchange) character. Each team's final output contributed one character to form the word “TRANSISTOR”, making the task interdependent.

For example, Team x decoding correctly would reveal the character ‘T’, Team y may yield ‘R’, and so on. After the group activity, a jumbled word is obtained which the whole class will decode the correct word.

A single mistake in any team like a wrong binary digit would alter the binary, leading to an incorrect decimal value and thus an incorrect ASCII character, disrupting the formation of the final word. This design forced precision, encouraged peer review, and emphasized team responsibility and inter-team collaboration. The core of the intervention was the design of a gamified binary decoding task, framed as a collaborative classroom challenge. This was not merely a quiz but a structured, immersive experience in which every student's contribution mattered and every team's accuracy was crucial to the overall class success. The addressed course outcome is to design digital combinational circuits.

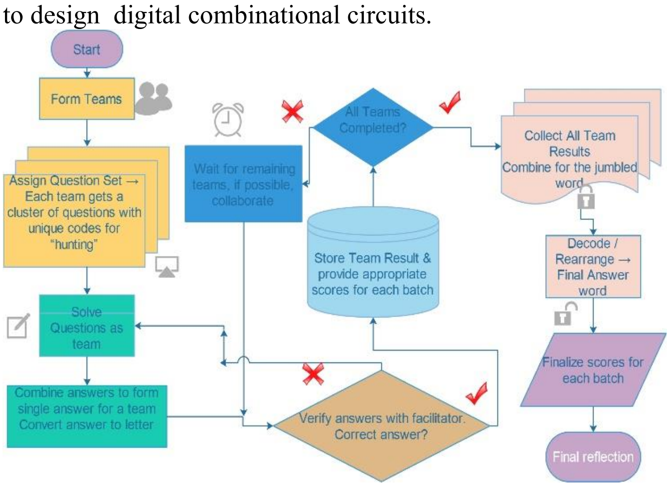

Fig. 2. Design flow of the CIPHER Model

Nature of Questions

The questions were mapped to Bloom's taxonomy (primarily levels 2-4: Understand, Apply, Analyse) and aligned to course outcomes, ensuring academic rigor. Topics included: “Logic gates (AND, OR, NOT, NAND, NOR, XOR, XNOR) , Boolean algebra simplification, Design of custom circuits using Karnaugh Maps, Multiplexers and Tri-state MUX, Encoders and Decoders, Priority Encoders, Gray Code to Binary conversion”

Figure 3 illustrates flow-chart of the Proposed Game Model for the Digital Systems Course

Layer 1 - C: Create

At this stage, AI tools (e.g., ChatGPT) were used to generate a diverse pool of binary logic problems based on keywords from the syllabus and course outcomes. These questions were manually reviewed and refined by the instructor to ensure clarity, alignment with learning objectives, and appropriate difficulty level. Each team was assigned a unique but comparable set of eight questions. The instructor acted as the essential filter. Generated content was not used raw. Final questions were selected based on relevance, familiarity (to the local student context), and clarity.

Prompt used in ChatGPT:

Design 80 application-based questions from digital systems topics such as Boolean Algebra, K-maps, multiplexers, demultiplexers, decoders, adders, and subtractors. Divide the questions evenly among 10 teams, with each team receiving 8 questions. Each question should have a binary answer (0 or 1). The sequence of 8 answers for each team must form an 8-bit binary number corresponding to the ASCII value of one letter from the word "TRANSISTOR". Ensure that the final output includes the questions, correct binary answers, the 8-bit code, and the decoded ASCII character for each team in a clear and structured format. Questions should be unique and non-repetitive across all teams to maintain variety and engagement. Overall, the activity should foster team-based problem solving through interesting and challenging tasks which makes students to be engaged in classrooms and by seeing the questions the students should not get bored.

The sample questions generated for one team of students is probided in Table I.

TABLE I
EXAMPLE QUESTIONS FOR A TEAM X (LETTER 'T')

Q. No	Question	Answer (Binary Bit)
1	A half-adder adds two binary digits. Predict the carry output when A = 1 and B = 0.	0
2	A full-adder has inputs A = 1, B = 1, and Cin = 0. Predict the sum output.	1
3	A 4:1 multiplexer has inputs I0 = 1, I1 = 0, I2 = 1, I3 = 1. If select lines S1S0 = 10, predict the output.	0
4	A 3:8 decoder has input A2A1A0 = 101. Which output line is activated (expressed in binary)? If Y5 is activated, return 1; otherwise, return 0.	1
5	A demultiplexer (1:8) receives an input of 1 and select lines 011. What is the output at Y3 (expressed in binary)?	0
6	A K-map for F (A, B, C) has min-terms (0,2,4,6). The simplified SOP expression has 3 terms. If true, return 1; otherwise, return 0.	1
7	A half-subtractor has inputs A = 1, B = 1. predict the difference output?	0
8	A binary parallel adder adds 1011 (11) + 0101 (5). The sum is 10000 (16). If there is a carry-out, return 1; otherwise, return 0.	0
	Team x (T) – 01010100f	

It should be noted that during the Create layer, AI-generated questions required refinement to ensure conceptual accuracy and appropriateness for Bloom’s levels. Table I shows questions after refinement and it is an essential step.

For example, the sixth question framed from AI is as follows: A K-map for F (A, B, C) has min-terms (0,2,4,6). The simplified expression has 3 terms. If true, return 1; otherwise, return 0. If students prefer working with POS format, the answer may go wrong. Hence, the question is reframed with the inclusion of SOP expression

Layer 2 – I: Involve

Students were divided into 10 balanced teams. The grouping was heterogeneous, based on prior performance and participation levels, to ensure equal opportunities and varied perspectives. Teams were briefed about the final objective forming the word "TRANSISTOR" by collectively solving and decoding their binary sequences. This layer instilled accountability at the individual and team levels and encouraged cooperation across teams.

Layer 3 - P & H: Predict & Hide

Each team worked on solving their assigned 8 questions. Every correct answer contributed a binary digit (0 or 1), forming an 8-bit sequence. This binary number was then:

1. Converted to its hexa-decimal equivalent
2. Mapped to the ASCII table
3. Resulted in a letter of the final word

Here's where the twist lay: the actual character that each team was expected to generate was not disclosed upfront. Only at the end would all teams come together to check whether the correct word ("TRANSISTOR") was formed. This added a hidden, suspense-driven dimension, promoting deep focus and logical accuracy.

Layer 4 - E: Engage

Once all teams had decoded their respective characters, they came together to arrange the characters in sequence. If the word "TRANSISTOR" was formed correctly, it was a collective win. If any team decoded an incorrect binary sequence, it could spoil the full word prompting peer review and inter-team troubleshooting. This stage triggered real-time collaboration, learning through correction, and whole class engagement. Students not only solved but helped each other, reinforcing the real-world importance of teamwork, communication, and precision in engineering design.

Layer 5 - R: Reflect

In the final stage, the teams reflected on:

1. How they approached their solutions
2. How they collaborated within and across teams
3. Where errors occurred (if any)
4. What they would do differently next time

Instructors used this stage to offer feedback, clarify doubts, and emphasize conceptual takeaways. Points were awarded for accuracy, teamwork, and clarity of explanation during the reflection. A feedback loop was optionally introduced where suggestions and reflections from Layer 5 informed improvements to question generation and team roles in Layer 1 for future iterations.

Team Coordination and Dynamics

One of the most powerful aspects of this method was the built in interdependence. Since the correctness of the final output (the word "TRANSISTOR") depended on every team getting their part right:

1. Students were naturally motivated to double-check their solutions
2. Stronger students assisted other teams
3. Mistakes became learning opportunities
4. A culture of mutual support and ownership was cultivated

Additionally, the activity encouraged self-regulation, time management, and even some role-based coordination, where team members naturally assumed positions like scribe, calculator, verifier, and spokesperson.

Digital and Analog Tools Used

The intervention employed a mix of low tech and AI-powered tools:

1. AI question generation using ChatGPT based on course objectives
2. Question sheets dissemination through online forum. Each team should hunt their questions in the group of questions posted.
3. Hexa-Decimal to ASCII charts for decoding
4. Whiteboards or screens for final word formation

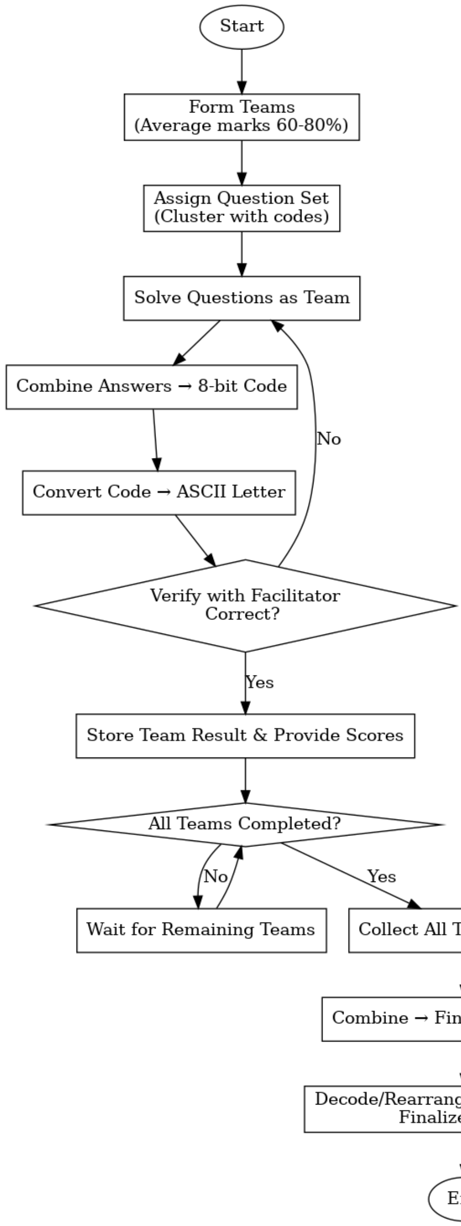

Fig. 3. Flowchart of the Proposed Game Model for the Digital Systems Course

Gamification Points System

Each team can earn a total of 10 points:

1. 8 points – For correctly solving and decoding their 8-bit binary character.

2. 2 points – For collaboratively arranging the final 10-letter word correctly.

The teams that complete their sequence correctly within the stipulated time earns 8 points. If any wrong letter is reported, then -1 for each wrong entry. If time crossed, -1 marks for each 3 minutes delay.

Pedagogical Integration

This methodology was not an isolated activity but carefully integrated into the instructional design of the course:

1. It followed a module on combinational logic circuits and the points are converted to a partial assignment marks
2. It preceded a mid-semester Continuous Assessment Test (CAT) and was directly mapped to Course Outcomes. It was assessed through both formative and summative feedback

Moreover, the success of this model reported in the faculty conclave of the institution inspired faculty in other departments such as Signals and Systems and Microprocessors to adopt similar gamified AI-assisted strategies.

IV. MATERIALS AND METHODS

This section details the context, participant distribution, and assessment mechanisms employed to evaluate the effectiveness of the CIPHER model in enhancing collaborative learning and problem-solving within a Digital Systems course. The methodology was designed to ensure a fair and comparative analysis between the traditional instructional approach and the proposed gamified framework.

Classroom Context and Participant Structure

The implementation took place in the first year Digital Systems course (Course Code: 22EE250) at a leading engineering institute. Two classes of nearly equal academic performance and faculty instruction were selected for a comparative study Class A (Experimental Group – 64 students) and Class B (Control Group – 66 students). Class A, comprising 10 teams, participated in the CIPHER-based gamified intervention, whereas Class B followed conventional teaching and assessment methods. This setup allowed for a comparative analysis of the effectiveness of gamified, AI-supported collaborative learning versus traditional classroom instruction.

Each question was crafted to require either direct binary logic application or reverse reasoning, integrating problem-solving and conceptual clarity. To control instructor bias, both Class A (experimental) and Class B (control) were taught by the same instructor using identical lesson plans, pacing, and assessment formats prior to the intervention. This ensured that differences in performance were attributed to the CIPHER model rather than instructional variability.

Test Element

To objectively assess the impact of the gamified model on academic performance, both sections underwent the same Continuous Assessment Test (CAT) following the completion of their respective instructional activities. The test consisted of application oriented and logic-based problems aligned with Bloom's Taxonomy (Levels 2 to 4 - Understand, Apply, Analyse) with Maximum Marks of 60.

Assessment Format: Combination of short-answer problem-solving and conceptual logic design tasks with the topics practiced during the gamified activity in Class A.

The test served as a summative evaluation tool to measure conceptual understanding, accuracy and problem-solving ability, offering a quantitative measure of learning outcomes.

Survey Element

After completing this activity on CIPHER model, the survey is taken in sending google forms to students, in that nearly 21 Questions asked and all are in 5- point Likert-scale based survey questions as it is prepared in table II and the parameters are mapped to particular research question. The likert scale varies from "strongly agree" to "strongly disagree". (Anitha, D., and D. Kavitha, 2022)

TABLE II
STUDENT SURVEY ELEMENTS

	SURVEY STATEMENT	CATEGORY	RQ-ID
SQ1	During the CIPHER activity, I felt more focused and attentive than in regular class sessions.	Classroom Experience	RQ3a
SQ2	Overall, I felt more engaged with the course material when using CIPHER than in standard instruction.	Classroom Experience	RQ3a
SQ3	The CIPHER activity made the classroom experience more enjoyable than a typical lecture.	Classroom Experience	RQ3a
SQ4	I actively participated in the group discussions during the activity	Collaborative Learning	RQ2
SQ5	My team members and I shared responsibilities equally while solving problems.	Collaborative Learning	RQ2
SQ6	I explained my ideas to my peers.	Collaborative Learning	RQ2
SQ7	I felt comfortable asking questions within the group.	Collaborative Learning	RQ2
SQ8	We discussed multiple solutions before arriving at a final answer.	Collaborative Learning	RQ2
SQ9	I used logical reasoning to support my group's decisions.	Higher-Order Thinking	RQ2
SQ10	I analysed the problem thoroughly before attempting a solution.	Higher-Order Thinking	RQ2
SQ11	I evaluated the pros and cons of different logic solutions.	Higher-Order Thinking	RQ2
SQ12	I created new approaches or strategies to solve the problem.	Higher-Order Thinking	RQ2
SQ13	The activity helped me apply theoretical concepts in practice.	Higher-Order Thinking	RQ2
SQ14	My team stayed focused and actively involved throughout the CIPHER activity	Team Engagement	RQ3c
SQ15	The collaborative nature of the activity helped maintain high energy in our team.	Team Engagement	RQ3c
SQ16	We collaborated to solve problems and made joint decisions.	Team Work	RQ3c

SQ17	My team members and I communicated effectively during the CIPHER activity.	Team Work	RQ3c
SQ18	The post-activity questions helped me evaluate my understanding of the concepts.	Reflective Learning	RQ3c
SQ19	The activity encouraged me to think critically about logic-based problems.	Reflective Learning	RQ3c
SQ20	The CIPHER activity enhanced my understanding of digital systems concepts comparably	Learning Experience	RQ3a
SQ21	The design and structure of the CIPHER activity (question clarity, logical flow, decoding process, and team collaboration) supported effective learning.	Instructional Design	RQ3a

To assess the quality and instructional value of the AI-generated questions used in the *Create* layer of the CIPHER model, feedback was collected from a panel of senior students and faculty experts in the Digital Systems domain. Their responses were captured through a structured Likert-scale survey focusing on five core indicators: relevance, outcome alignment, personalization, difficulty adaptation, and theoretical application and the survey questions are provided in Table III.

TABLE III
EXPERT SURVEY ELEMENTS

Item No.	Survey Statement	Category	RQ-ID
Q1	The AI-generated questions, post-instructor review, accurately map to the prescribed course learning outcomes.	AI integration	RQ3b
Q2	The personalized contexts and difficulties introduced by the AI-generated questions are well-suited to diverse student skill levels.	AI integration	RQ3b
Q3	These AI-assisted questions enhance the relevance and application of theoretical concepts taught in the course.	AI integration	RQ3b
Q4	Implementing AI-generated question design improved efficiency without compromising academic rigor or content quality.	AI integration	RQ3b
Q5	Overall, AI-generated and curated questions provided a more effective assessment tool than traditional instructor-designed questions.	AI integration	RQ3b

Ethical Considerations

All student participants were informed about the instructional intervention and its research purpose. Participation in survey activities and gamified exercises was voluntary, with anonymity maintained during data analysis. No academic penalties or grading differences were imposed based on participation.

V. RESULTS AND DISCUSSIONS

This section presents a comprehensive evaluation of the CIPHER model, organized around the four research questions that guided this study. Our findings stem from classroom implementations, performance data, student feedback, and peer observations. Together, these insights showcase how CIPHER functions not just as a gamification model, but as a dynamic framework that fosters deeper learning and collaboration.

Our journey with CIPHER began in a second-year core course, Digital Systems. With 64 undergraduate students participating, we transformed a traditionally lecture driven module into an interactive, AI-supported, and student-centred experience. The gamified activity, structured around the CIPHER framework, challenged students to collaboratively decode the word "TRANSISTOR", with each letter linked to course aligned logic problems.

A. Research Question 1- Results and Discussions

What is the impact of the CIPHER gamification model on students' academic performance compared to traditional instructional methods?

To assess the impact of the CIPHER gamification model on academic performance, we conducted a controlled experiment with two sections of a Digital Systems course: Class A (n = 64), where the CIPHER model was implemented, and Class B (n = 66), which followed a traditional lecture-based approach. Both classes were assessed using the same Continuous Assessment Test-1 (CAT1) with a total score of 60.

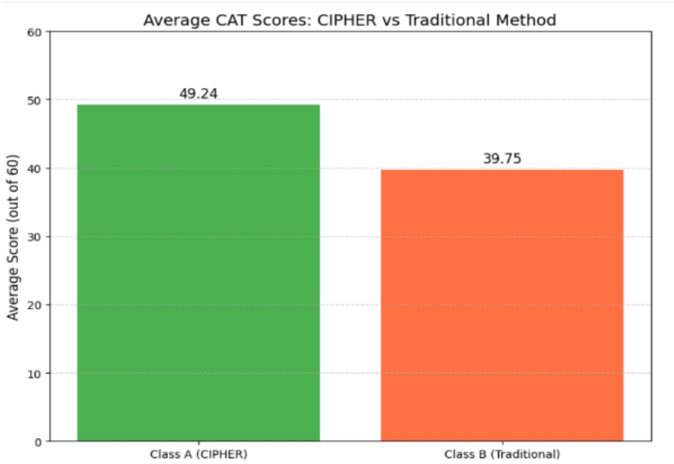

Fig. 4. Average CAT-1 scores

The Average CAT scores were shown in Figure 4 and we applied an independent samples T-test, a standard method used to compare the means of two unrelated groups. Prior to conducting the t-test, assumptions of normality and homogeneity of variances were verified.

T-test Procedure

Test type: Two-tailed independent samples T-test

Null hypothesis (H_0): There is no difference in mean CAT scores between Class A and Class B.

Alternative hypothesis (H_1): There is a significant difference in mean CAT scores between the two groups.
Significance level (α): 0.05
The test produced a t-statistic of 10.49 and a p-value of 5.98×10^{-19}, which is significantly below the 0.05 threshold. Thus, we reject the null hypothesis and conclude that the CIPHER model had a statistically significant positive effect on students' academic performance compared to traditional instruction.
This result highlights that integrating game-based learning elements through the CIPHER model not only increased student interest but also improved their academic outcomes. The interactive and collaborative nature of the activity, combined with AI-generated, outcome-aligned logic challenges, likely contributed to better conceptual understanding and knowledge retention.
In addition to academic performance, student engagement during classroom activities was also assessed. Based on post-activity survey responses, the CIPHER model made the learning process more engaging and interactive and shown in figure 5. This perception aligns with increased participation and attentiveness observed during the sessions. Furthermore, Class A recorded a 95% attendance rate on the activity day, indicating high interest and voluntary involvement. These indicators collectively suggest that the gamified learning experience through CIPHER significantly enhanced classroom engagement.

B. Research Question 2- Results and Discussions

How does the CIPHER model influence student's collaborative learning processes and development of higher-order thinking skills during problem-solving activities?

To investigate the impact of the CIPHER model on student's collaborative learning and higher-order thinking skills (HOTS), a structured survey was administered to 64 undergraduate students after engaging in a gamified collaborative activity. The CIPHER activity involved solving a series of binary logic problems that decoded to ASCII characters, which collectively formed the word "TRANSISTOR." Each team member contributed by solving one problem, and the group had to coordinate to decode the final word. The survey questions were asked after conducting the activity by cipher model, table III represents the student's response on collaborative learning and higher order thinking

Impact on Collaborative Learning

As observed from the survey data, Table I presents the survey responses from students collected after the implementation of the CIPHER model, reflecting their perceptions of its impact on collaborative learning. The CIPHER activity encouraged active team-based participation and mutual accountability. Students reported being engaged in discussions and sharing responsibilities, which is consistent with collaborative learning literature. The structure of assigning one binary logic problem per member created natural interdependence. This ensured not only equal participation but also enabled informal peer teaching. Such dynamics are less evident in traditional classroom setups and highlight CIPHER's strength in fostering a supportive collaborative environment. Table III provides the mean and standard deviation of the responses received from the students.

TABLE III
SURVEY ON COLLABORATIVE LEARNING & HOTS

SQ.NO	Mean	SD
SQ4	4.41	0.62
SQ5	4.28	0.69
SQ6	4.35	0.66
SQ7	4.33	0.72
SQ8	4.22	0.71
SQ9	4.31	0.69
SQ10	4.25	0.74
SQ11	4.13	0.77
SQ12	4.27	0.81
SQ13	4.38	0.62

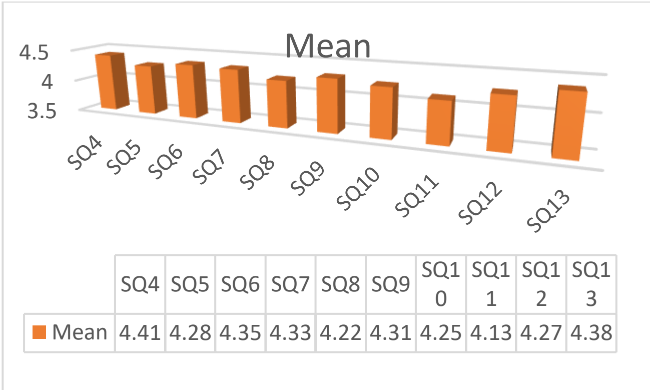

Fig. 5. Representation of Mean of the survey elements corresponding to collaborative learning and HOTS

Impact on Higher-Order Thinking Skills (HOTS)

Beyond collaboration, the activity stimulated higher-order thinking. By survey data, Table I presents the students responses for the implementation of the CIPHER model, highlighting its effectiveness in fostering higher-order thinking skills during problem-solving activities. For example, several students reported experimenting with new strategies rather than relying on textbook methods a sign of cognitive flexibility and heuristic development. The task design implicitly pushed students to apply, analyse, and create three upper levels of Bloom's taxonomy. This shows that gamified learning, when structured effectively, can transition students from rote application to problem-solving and reasoning, essential for competitive exams and real-world digital system challenges.

Post-Activity HOTS Assessment GATE-Level Question

To validate the development of higher-order thinking, a GATE-level digital logic problem was administered immediately after the activity. The question required students to apply their understanding of logic gates, binary conversions, and circuit behaviour in a novel context without group support. Unlike survey responses, the post-activity GATE-level question acted as a performance-based assessment. Success in this task indicated a genuine transfer of learning, as students applied logical reasoning in a novel context. 65% of the students addressed the problem and

works out the solution. This serves as stronger evidence for the development of HOTS than self-reported data alone.
Students who had just completed the CIPHER activity demonstrated greater confidence and accuracy in solving this advanced question, suneggesting a clear transfer of skills from the gamified collaborative environment to an individual high-stakes task. This final assessment confirmed that students were not only engaged during the activity but had also internalized the cognitive processes required to tackle real-world or competitive exam-level problems.

C. Research Question 3a- Results and Discussions
What are student's perceptions of the CIPHER model in terms of its instructional design, learning value, and overall classroom experience?

The student's perception of the CIPHER model was overwhelmingly positive in terms of instructional clarity, motivation, and overall classroom experience. As illustrated in Figure 6, all survey items received high average ratings, with mean scores ranging from 4.25 to 4.59 on a 5-point Likert scale. This indicates that participants consistently agreed or strongly agreed with the statements presented.

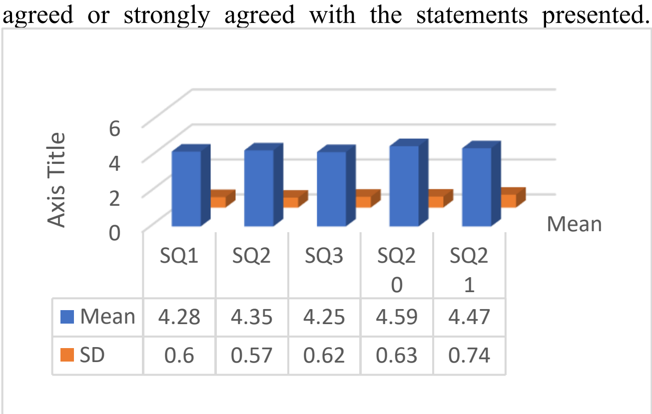

Fig. 6. Student Perception related to RQ3a

The highest-rated aspect was the student's sense of increased motivation during the activity compared to regular sessions. This outcome reflects the success of the Engage layer of the CIPHER framework, which used elements of gamification such as the decoding of the word "TRANSISTOR" to create a competitive and curiosity-driven environment. This likely enhanced intrinsic motivation and sustained attention throughout the session.
Equally strong agreement was observed regarding the clarity of instructions and the transparency of learning objectives, which can be attributed to the structured and linear nature of the model's Create layer. By integrating AI-generated logic problems that were directly aligned with course outcomes, the model helped students navigate the task with clear goals and expectations.
Additionally, the feedback showed that students found the overall classroom experience to be enjoyable and interactive. A majority of students even expressed interest in experiencing similar activities in other subjects, highlighting the model's perceived value beyond a single session.

Taken together, the high levels of agreement across all items suggest that the CIPHER model successfully enhanced both the instructional delivery and the emotional engagement of students, offering a more structured, motivating, and collaborative learning experience compared to conventional approaches.

Research Question 3b - Results and Discussions

How effective is the integration of AI-generated, instructor - curated questions (Layer 1: Create) in and outcome-based learning?
The survey questions asked to senior students and faculty experts and their responses on cipher model for AI generated questions was shown in Figure 4, Expert perceptions were overwhelmingly positive, with all evaluated dimensions receiving mean ratings above 4.3 on a 5-point scale. The highest endorsement was observed for alignment with course outcomes, followed closely by the application of theoretical concepts highlighting the effectiveness of AI-assisted question design in maintaining academic rigor and conceptual relevance. Totally 23 senior students with A+ grades in the course and 4 expert faculty reviewed the questions and participated in the survey.

TABLE IV
SURVEY ON AI INTEGRATION IN CIPHER BY EXPERTS

Item No.	Mean	SD
Q1	4.52	0.67
Q2	4.38	0.72
Q3	4.49	0.65
Q4	4.42	0.69
Q5	4.36	0.75

Although all areas scored well, the relatively lower score for adaptive difficulty suggests potential for fine-tuning the AI model to better match varying learner levels. Nonetheless, the overall feedback validates the Create layer's potential to deliver customized, curriculum-aligned learning experiences that support both instructional goals and learner engagement. Figure 7 provides the radar chart of experts perception of AI generated questions.

Research Question 3c - Results and Discussions
In what ways does the layered structure of CIPHER (Create, Involve, Predict & Hide, Engage, Reflect) foster teamwork, and reflective learning behaviours?
To examine how each layer of the CIPHER framework influences sustained engagement, collaborative behaviour, and reflective learning, students responded to a set of Likert-scale items after completing the activity. The results are illustrated in Figure 8, a bar chart that presents the combined mean scores for three core dimensions Engagement, Teamwork, and Reflection across all five layers of the model.

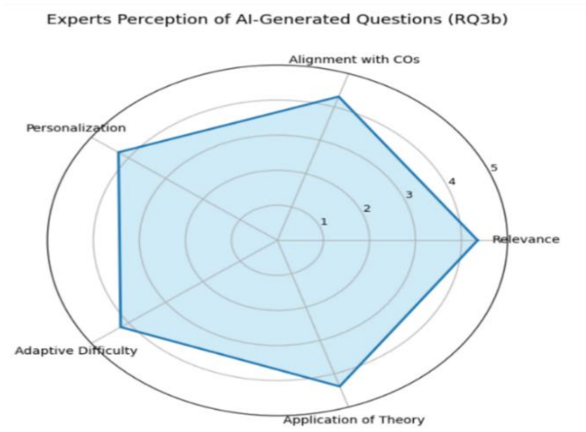

Fig. 7. Experts perception of AI generated questions.

While the visual chart conveys relative intensities across layers, several noteworthy insights emerge upon deeper analysis. The Engage and Involve layers consistently stood out for fostering active group participation and peer collaboration. This highlights the critical role of game-based challenges and structured team roles in sustaining attention and strengthening interdependence among learners.

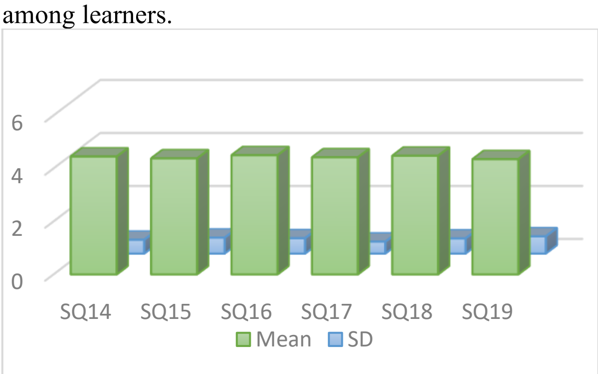

Fig. 8. Survey on CIPHER for team works and learning

It demonstrated the strongest response in reflective learning, indicating that students deeply processed their learning when given a chance to revisit problems independently.

The Predict & Hide phase's performance points to the motivational value of uncertainty keeping students alert and engaged through anticipation, which inherently promoted strategic thinking within teams.

The Create layer, although foundational, showed slightly lower engagement scores possibly because this phase is more instructor/AI-driven and less interactive by nature. However, its role in scaffolding logical thinking and establishing a cognitive base for the subsequent layers remains essential.

Overall, the figure affirms that the layered structure of CIPHER is not merely sequential but synergistic with each layer contributing uniquely to a combination of cognitive, collaborative, and reflective learning outcomes. This structured progression supports sustained engagement and makes the model adaptable for repeated use across varying content areas and learning levels. The proposed gamification model after its first implementation in Digital Systems course for the first year students was presented at a Faculty Conclave in the college, where it won the Best Strategy Award. Following this recognition, three faculty members applied the model in different subjects and across various year levels as mentioned in table V. In all three cases, surveys and observations indicated consistent engagement, adaptability, and positive reception among students. Faculty noted that the model's framework was flexible enough to be tailored while preserving its core benefits. These cross-course applications validate the CIPHER model as a scalable and interdisciplinary pedagogical tool, particularly suited for outcome-based learning mandates in technical education.

TABLE V
FURTHER IMPLEMENTATION OF CIPHER MODEL

S.No	Discipline	Course	Students strength	Year of study
1	Data Science	Data Mining	40	III
2	Information Technology	Data Structures	75	II
3	EEE	Machine Learning	67	IV

In each of these courses, the core CIPHER structure was retained while the nature of logic questions, decoding tasks, and collaborative activities were adapted to the specific course outcomes. For instance, in Data Mining, numerical problem-solving was used for binary decoding; in Data Structures, pointer-based reasoning tasks replaced circuit logic questions; and in Machine Learning, conceptual prediction questions were encoded into the gamified flow. These modifications demonstrate that the model can be easily scaled and tuned to discipline-specific requirements.

The model's flexible structure allows educators to use it fully or partially, based on the course requirements, making it suitable for theory-based as well as practical subjects in offline, online, or hybrid settings. Its broader adoption depends on factors like teacher readiness, institutional support, flexible curriculum, and faculty training. Overall, the CIPHER model helps make learning more engaging, collaborative, and effective across disciplines. Hence, the CIPHER model is scalable and adaptable to other technical courses or interdisciplinary subjects.

VI. FUTURE IMPLEMENTATION

A. Observations And Future Directions

The deployment of the CIPHER model revealed more than just an uptick in academic performance it showcased a pedagogical shift in how students learn, think, and collaborate. From the very first layer AI-generated logic puzzles to the reflective wrap-up at the end of each session, students were no longer passive recipients of knowledge. Instead, they became active participants in a dynamic, gamified learning experience. The model promoted deep thinking, peer learning, and strategic engagement, all while aligning with curriculum outcomes.

The future direction for CIPHER involves developing a lightweight digital platform that automates question generation, team allocation, scoring, and feedback delivery. Integrating AI tutors, dynamic difficulty adjustment, and analytics dashboards will further strengthen personalization and allow instructors to track learning patterns in real time. These improvements will enhance scalability while preserving the model's collaborative and reflective core.

Additionally, AI-generated questions can be aligned with different learners' styles and from the feedback of the learners, content delivery shall be planned further.

This direction is not just an upgrade; it's a reinvention where gamification, AI, and pedagogy intersect to redefine the boundaries of engagement and effectiveness in higher education.

B. *Difficulties faced*

While the implementation journey was inspiring, it was equally demanding. One of the foremost challenges was the manual orchestration of the model from question generation to team coordination and response validation. Without a dedicated platform, instructors had to spend significant time curating and managing each session. Moreover, the absence of real-time automated feedback meant that students sometimes missed the chance to correct and learn from their errors instantly. Limited technological resources, especially in non-smart classrooms, posed further constraints, requiring improvisation and additional facilitation. Another significant difficulty was the variation in student adaptability. While many thrived in the gamified format, a few took time to adjust, initially struggling to balance playfulness with academic rigor. Designing activities that were both challenging and inclusive demanded constant iteration.

Yet, these difficulties became catalysts for innovation. Each roadblock illuminated what the next version of CIPHER needed automation, adaptability, and accessibility. These experiences weren't setbacks; they were stepping stones that clarified the path forward. In retrospect, the challenges endured were not just technical they were part of the transformation process. And it is through these very struggles that CIPHER finds its strength as a model born in a classroom, tested through trial, and refined for the future.

CONCLUSION

This study explored the impact of AI-augmented gamification on collaborative learning in a Digital Systems course through the implementation of the CIPHER model. The research was guided by three key questions concerning the effectiveness of gamified learning, collaborative engagement, and the role of AI in personalized question generation. The activity, designed as a five-layer gamified framework, embedded logical decoding and team-based problem-solving into the course structure.

Assessment data including CAT scores and qualitative feedback revealed improved conceptual understanding, increased engagement, and enhanced collaboration among students in the CIPHER-enabled classroom compared to the traditional cohort. The reflective layer of the model provided actionable insights for both learners and instructors, allowing for adaptive teaching strategies.

The findings validate the effectiveness of integrating structured gamification with AI support in core engineering education. The CIPHER model's modularity and course neutrality make it adaptable across various disciplines. The research outcomes affirm that such pedagogical innovation can significantly enrich the learning experience and improve measurable outcomes.

In conclusion, the CIPHER model offers a scalable, sustainable, and adaptable learning structure. By merging AI tools with student-centred pedagogy, it supports deeper engagement, teamwork, and reflective learning attributes essential for effective education in 21st-century technical and interdisciplinary classrooms.

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