

Optimizing Active Learning With Cognitive Load And Dual Coding Theories: A Quasi-Experimental Study On Student Performance In Higher Education

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Abstract. Higher education faces challenges in developing high-level cognitive skills in students, with many learning approaches still ignoring cognitive principles. This study aims to test the effectiveness of integrating Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) in active learning to reduce excessive cognitive load and improve student understanding, memory, and motivation. A quasi-experimental design was used involving 64 undergraduate students who were divided into two groups: an experimental group that received CLT and DCT-based active learning, and a control group that followed conventional active learning. Data were collected through pre-test and post-test, semi-structured interviews, and classroom observations, and analyzed using t-test, MANOVA, and qualitative thematic analysis. The results showed that the experimental group obtained significantly higher post-test scores, with almost twice the improvement in learning compared to the control group. Qualitative analysis showed that CLT successfully reduced unnecessary cognitive load, while DCT strengthened comprehension through visual-verbal integration. College students also report higher engagement and ongoing motivation. This research makes an original contribution by proving the benefits of the combination of CLT and DCT in active learning, as well as offering a research-based framework to create a more effective and engaging learning environment in the digital age.

Keywords: *cognitive theories, student engagement, learning outcomes, higher education, instructional design.*

INTRODUCTION

Higher education is currently facing significant challenges in improving the effectiveness of learning—not merely by relying on one-way teaching methods, but also by optimizing the development of students' higher-order cognitive skills, such as analysis, problem-solving, and the application of knowledge in real-world contexts [1], [2], [3]. Active learning, which directly engages students in the learning process, has been shown to be more effective than traditional, passive teaching methods that often emphasize rote memorization without deep understanding [4], [5], [6].

Data from several studies indicate that the implementation of active learning strategies enhances students' academic performance, particularly in tasks that require deep conceptual understanding and the application of knowledge [7], [8], [9]. However, despite the many recognized benefits, the adoption of active learning is often hindered by a lack of understanding regarding how to effectively integrate cognitive theories—such as Cognitive Load Theory (CLT) and Dual Coding Theory (DCT)—to optimize instructional design and improve learning outcomes [10], [11].

Related studies reveal that although many universities have begun incorporating active learning, uncertainty remains regarding its impact on students' cognitive load and how cognitive theories can be more effectively applied in teaching practices [12], [13], [14]. In this context, surveys conducted by various higher

education institutions show that many educators struggle to effectively optimize active learning, particularly in designing instructional materials that reduce cognitive load without compromising students' depth of understanding [15].

This study aims to address these challenges by exploring how the application of Cognitive Load Theory and Dual Coding Theory can both reduce cognitive load and enhance students' academic performance in higher education. Recent research shows that integrating CLT and DCT into active learning contexts can improve student learning outcomes, especially in teaching that demands high-level cognitive skills [16], [17]. CLT emphasizes the management of cognitive load to optimize short-term memory capacity, while DCT incorporates both visual and verbal representations to enrich conceptual understanding [18].

Nonetheless, much of the literature remains limited in its exploration of how these two theories can be systematically integrated into active learning practices, with a greater focus on quantitative outcomes measuring academic achievement rather than deeper cognitive processes [19], [20]. Although many studies highlight the benefits of CLT and DCT in education, a research gap persists regarding how these theories can be comprehensively integrated into active learning methods. Existing studies have yet to fully examine how CLT and DCT can directly reduce cognitive load while simultaneously enhancing student engagement in the development of high-order skills such as problem-solving and concept application.

This gap has led to a lack of understanding of how to optimize these theories within instructional design to improve students' learning experiences. Therefore, this study seeks to explore and address this gap in the literature by examining how the integration of Cognitive Load Theory and Dual Coding Theory in active learning can enhance academic performance and reduce students' cognitive load during the learning process.

The implementation of CLT and DCT in active learning is increasingly urgent, given the growing complexity of skill demands in the workplace, which require high-level thinking and problem-solving abilities [14], [21]. Without this research, there is a risk of continuing to rely on less effective teaching methods that may exacerbate issues related to students' low engagement and poor understanding of instructional content. Furthermore, without a thorough understanding of how to manage cognitive load in active learning, instruction may become ineffective—leading to boredom and mental fatigue among students, which can ultimately diminish their academic achievement [8], [22].

This study makes a significant contribution to the development of active learning by integrating cognitive theories such as CLT and DCT. By investigating how these theories can reduce cognitive load and improve students' comprehension and application of concepts, this research aims to provide empirical evidence that supports the development of more effective teaching strategies in higher education. The findings are also expected to offer new insights into designing more adaptive instruction, helping students better navigate academic challenges in the digital era.

METHODS

Research Design

This research utilized a quasi-experimental design that involved two groups receiving different instructional treatments [23], [24], [25]. The experimental group engaged in active learning strategies grounded in Cognitive Load Theory (CLT) and Dual Coding Theory (DCT), whereas the control group participated in conventional active learning activities without incorporating these theoretical frameworks. A quasi-experimental approach was chosen because it enables researchers to work with existing groups without random assignment, which is often not feasible in higher education settings [26]. Furthermore, the study employed a mixed-methods design, combining quantitative and qualitative data to achieve a more thorough understanding of the effectiveness of integrating these cognitive theories into active learning practice.

Participants

This research included 64 students enrolled in the Islamic Education (PAI) program at Universitas Muhammadiyah Surakarta (UMS), Indonesia, who were assigned to two groups. The experimental group consisted of 31 students from Class A and took part in active learning activities grounded in Cognitive Load Theory (CLT) and Dual Coding Theory (DCT). Meanwhile, the control group included 33 students from Class B, who participated in active learning without incorporating these cognitive frameworks.

Participants were chosen because they were enrolled in the same academic program and course, particularly a subject that could benefit from the application of CLT and DCT. This grouping strategy was designed to minimize the influence of external factors, such as variations in students' academic abilities or educational backgrounds, that could affect the study's results.

Instruments

The research instruments employed in this study included three primary components: a pre-test, a post-test, and semi-structured interviews. The pre-test and post-test were developed to assess changes in students' conceptual understanding and ability to apply the material before and after the instructional intervention. These assessments contained items designed to evaluate students' comprehension, application, and analytical skills related to the instructional content. The pre-test was administered prior to the learning sessions, while the post-test was conducted following the implementation of the active learning activities.

Additionally, semi-structured interviews were carried out with selected students from both the experimental and control groups to gather qualitative insights into their learning experiences during the CLT- and DCT-based active learning sessions. The interviews focused on students' perceptions of cognitive load management and the effectiveness of using visual and verbal representations in facilitating learning.

All instruments were developed in accordance with the principles of Cognitive Load Theory (CLT) and Dual Coding Theory (DCT), ensuring that key aspects of cognitive load reduction and dual representation were adequately addressed. Prior to the main study, the instruments were pilot-tested with a different group of students to assess item clarity and relevance. Revisions were subsequently made based on feedback from expert validators to improve the instruments' validity and reliability, including clarifying ambiguous items and aligning them more closely with the instructional content.

Data Collection Methods

The data for this study were collected through three main methods. First, pre-tests and post-tests were administered to evaluate changes in students' conceptual understanding and application skills among those who participated in active learning based on Cognitive Load Theory (CLT) and Dual Coding Theory (DCT), as well as students in the control group. These assessments provided quantitative evidence of students' academic progress following the instructional intervention.

Second, semi-structured interviews were conducted with selected participants from both groups to obtain in-depth insights into their experiences and perceptions of the active learning process. The interviews generated qualitative data related to cognitive load management and students' experiences with visual and verbal representations in learning.

Third, classroom observations were conducted during the learning sessions to examine student engagement levels and to monitor the implementation of the active learning strategies employed.

Data Analysis

The data obtained in this study were examined using both quantitative and qualitative analysis methods [27]. Quantitative data from the pre-test and post-test were analyzed using a t-test to compare the performance of the experimental and control groups. This statistical analysis was conducted to identify whether significant differences existed in students' academic achievement after the implementation of active learning based on Cognitive Load Theory (CLT) and Dual Coding Theory (DCT).

Furthermore, the interview data were analyzed through thematic analysis, which involved identifying and interpreting key themes related to students' experiences during active learning. This approach provided insights into students' perceptions of how the application of cognitive theories contributed to reducing cognitive load and improving conceptual understanding. The integration of quantitative and qualitative analyses offered a more comprehensive understanding of the effects of applying CLT and DCT in an active learning context.

RESULTS AND DISCUSSION

Quantitative Data Results

This research involved two groups: Class A as the experimental group with 31 students and Class B as the control group with 33 students. Both groups completed a pre-test and a post-test administered before and after the instructional intervention. The intervention involved applying active learning strategies grounded in Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) in Class A, whereas Class B participated in active learning activities without incorporating these theoretical approaches. Descriptive statistics for the pre-test and post-test scores of both groups are shown in Table 1:

Table 1. Descriptive Statistics of Pre-Test and Post-Test

Class	N	Minimum	Maximum	Mean	Std. Deviation
Class A (Experimental) Pre-Test	31	45	80	63.2	9.13
Class A (Experimental) Post-Test	31	60	92	78.9	8.32
Class B (Control) Pre-Test	33	43	78	62.5	8.76
Class B (Control) Post-Test	33	55	85	70.3	7.84

The mean pre-test scores of both groups were fairly comparable, indicating that students began the study with similar levels of ability. After the instructional intervention, however, Class A demonstrated an average increase of nearly 16 points, while Class B showed an improvement of approximately 8 points. These results indicate that the learning approach incorporating Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) produced a stronger effect on students' learning outcomes.

Prior to further statistical analysis, the data were examined for normality and homogeneity. The Kolmogorov–Smirnov test confirmed that all datasets were normally distributed ($p > 0.05$), and Levene's test indicated that the variances between groups were homogeneous ($p > 0.05$). As a result, the data satisfied the assumptions for parametric testing, allowing the analysis results to be regarded as reliable. In addition, the learning outcome assessment instruments were evaluated for validity and reliability, ensuring the accuracy and consistency of the measurement tools.

Table 2. Validity Test Results

No	$r_{\text{calculated}}$	$r_{\text{critical}} (n=64, \alpha=0.05)$	Remarks
1–20	0.36 – 0.63	0.244	All valid

All test items in table 2 demonstrated item-total correlation values exceeding the critical r-value, indicating that each item consistently measured the intended construct. Therefore, no items required elimination, and the overall instrument was deemed valid for use.

Table 3. Reliability Test Results

Instrument	Cronbach's Alpha	Remarks
Learning Outcome Test	0.87	Reliable

The Cronbach's Alpha value was 0.87 (see table 3), which is well above the minimum acceptable threshold of 0.70, indicating that the instrument had high reliability. This suggests that students' responses were consistent and that the instrument demonstrated strong internal stability. Subsequently, a comparative analysis was conducted between the pre-test and post-test scores within each class.

Table 4. Paired Samples Test – Class A (Experimental)

Pair	Mean Pre	Mean Post	t	df	Sig. (2-tailed)
Pre – Post	63.2	78.9	-9.874	30	0.000

In Class A, the results showed a substantial increase of 15.7 points (see Table 4). The t-test analysis produced a p-value below 0.05, indicating that the observed improvement was statistically significant and unlikely to have occurred by chance. These findings provide strong evidence that learning instruction grounded in Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) is effective in significantly enhancing students' academic performance.

Table 5. Paired Samples Test – Class B (Control)

Pair	Mean Pre	Mean Post	t	df	Sig. (2-tailed)
Pre – Post	62.5	70.3	-6.425	32	0.000

Class B also demonstrated a significant improvement of 7.8 points (see Table 5); however, this increase was considerably smaller than that observed in Class A. This finding suggests that although active learning positively influences student achievement, its impact is substantially reduced when not supported by the principles of Cognitive Load Theory (CLT) and Dual Coding Theory (DCT). An independent t-test was subsequently performed on the post-test scores to compare the performance of the two groups.

Table 6. Independent Samples Test – Post-Test

Group	Mean Post	t	df	Sig. (2-tailed)	Mean Difference
Class A vs Class B	78.9 vs 70.3	4.127	62	0.000	8.57

The results presented in Table 6 revealed a significant difference between Class A and Class B, with a mean score gap of 8.57 points. This outcome indicates that students who received instruction incorporating Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) consistently attained higher learning outcomes than those who engaged in conventional active learning. To further support these findings, a MANOVA was performed on the pre-test and post-test scores of both groups.

Table 7. MANOVA Results (Pre-Test and Post-Test)

Effect	Wilks' Lambda	F	df	Sig.
Class	0.732	5.684	2, 61	0.006

The Wilks' Lambda value of 0.732 with $p < 0.05$ indicates a statistically significant multivariate difference between Class A and Class B (see table 7). This result confirms that the integration of Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) influenced not just a single aspect, but enhanced students' overall learning achievement. To visualize the increase in average scores, the following graph is presented.

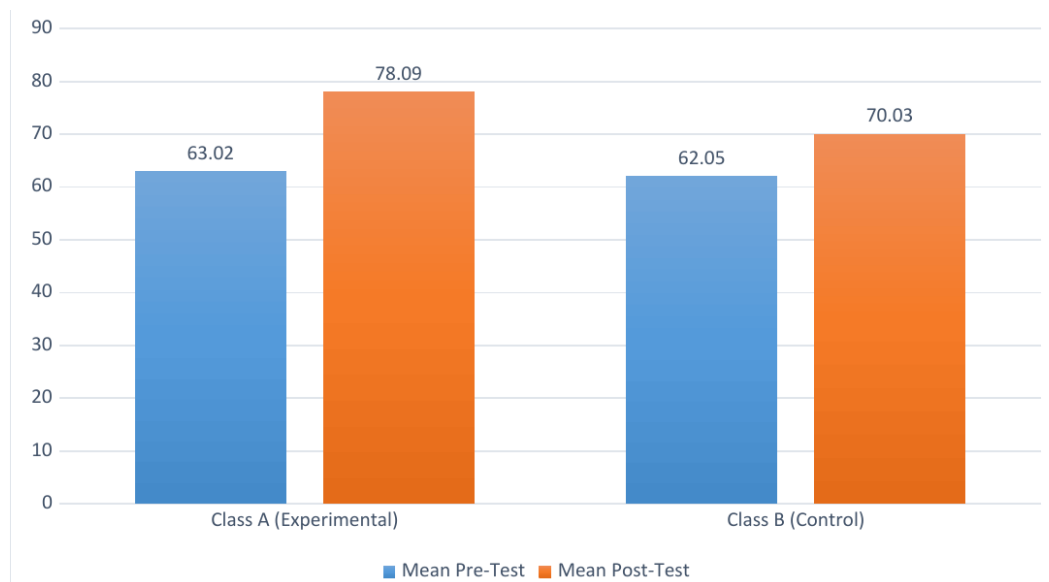


Figure 1. Comparison of Average Pre-Test and Post-Test Scores

Source. Data from interviews with informants.

Figure 1 shows that the improvement in mean scores for Class A was considerably higher than that of Class B. In addition to achieving greater score gains, students in Class A also exhibited a score distribution that was more concentrated in the higher range (80 and above). These results further support the conclusion that incorporating Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) into active learning positively influences students' academic achievement by fostering deeper understanding and more effective application of concepts.

Qualitative Data Results

The interviews conducted with students from Class A (experimental group) provided valuable insights into their experiences with active learning integrated with Cognitive Load Theory (CLT) and Dual Coding Theory (DCT). Overall, students described the learning process as more manageable, engaging, and effective compared to their usual classes.

Several students explained that the lessons felt less overwhelming because the material was broken down into smaller steps and presented in a structured manner. They highlighted that this approach helped them process the content more easily and prevented them from feeling cognitively overloaded. One student expressed, "the lessons no longer felt too heavy because the information was given in parts, making it easier to follow step by step." This indicates that the application of CLT successfully reduced extraneous cognitive load, allowing students to focus their mental resources on the core concepts.

Another common observation was the usefulness of combining visual and verbal representations. Students consistently stated that the use of diagrams, flowcharts, and visual illustrations alongside verbal explanations reinforced their understanding. One student noted, "when I saw the diagram and listened to the explanation at the same time, it was easier for me to connect the concepts." This feedback illustrates the positive impact of DCT, which leverages dual channels of processing to strengthen comprehension and memory.

The qualitative data also revealed that students felt they understood and retained the material better compared to traditional approaches. Some mentioned that the visuals helped them remember the concepts days after the lesson, supporting the claim that the integration of DCT with CLT fosters long-term retention as well as immediate comprehension. A participant shared, "I could still remember the material even days later because the visuals stayed in my mind."

Finally, students described the learning atmosphere as more engaging and motivating. They were encouraged to participate more actively and found the activities enjoyable, which contrasted with their experience in more lecture-based formats. As one student reflected, "I felt more motivated to learn because the class activities made me want to participate instead of just listening passively." This demonstrates that the combined approach not only improved learning performance but also enhanced students' enthusiasm and active involvement in class. To further illustrate these findings, the main themes from the interviews are summarized in table 8 below.

Table 8. Thematic Summary of Student Interviews

Theme	Student Quote	Interpretation
Reduced Cognitive Load	<i>"The lessons no longer felt too heavy because the information was given in parts, making it easier to follow step by step."</i>	CLT helped reduce extraneous cognitive load, making learning more manageable.
Benefits of Visual + Verbal	<i>"When I saw the diagram and listened to the explanation at the same time, it was easier for me to connect the concepts."</i>	DCT reinforced understanding by using dual channels of information processing.
Improved Retention and Recall	<i>"I could still remember the material even days later because the visuals stayed in my mind."</i>	Visual-verbal integration supported long-term retention and deeper learning.
Increased Engagement & Motivation	<i>"I felt more motivated to learn because the class activities made me want to participate instead of just listening passively."</i>	The integration of CLT and DCT within active learning fostered motivation and participation.

This table shows that students experienced reduced cognitive load, benefited from visual-verbal representations, retained the material more effectively, and felt more engaged throughout the learning process. These perspectives complement the quantitative results, confirming that integrating CLT and DCT into active learning creates a more effective and meaningful learning environment for higher education students.

Cognitive-Theoretical Support for Active Learning

The findings of this study offer strong empirical support for the position that active learning realizes its pedagogical potential only when it is systematically anchored in cognitive learning theory. Although active learning has been widely promoted as a remedy for passive instruction, the literature presents a fragmented and sometimes contradictory picture regarding its effectiveness [15], [28]. Numerous studies report positive effects on engagement and performance, while others document mixed or negligible gains, particularly among novice learners. These inconsistencies suggest that active learning, as commonly implemented, often lacks a clear theoretical mechanism explaining why and under what conditions it improves learning [29], [30]. The present study addresses this unresolved issue by demonstrating that Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) provide the missing cognitive foundation that explains both the successes and failures reported in prior research.

A critical limitation in much of the active learning literature is the implicit assumption that increased learner activity inherently leads to deeper understanding. This assumption, while pedagogically appealing, stands in tension with cognitive theory. From a CLT perspective, active learning frequently increases intrinsic and extraneous cognitive load by requiring learners to simultaneously process content, manage social interaction, and generate responses [16]. Several studies have cautioned that such demands may overwhelm working memory, particularly for students with limited prior knowledge, yet these warnings are often overlooked in practice [31], [32]. The significant learning gains observed in the experimental group of this study provide clear evidence that when CLT principles are deliberately embedded—through segmentation, task sequencing, and instructional scaffolding—active learning can avoid cognitive overload and instead support effective schema construction [14].

These findings directly challenge a dominant narrative in the literature that frames active learning as a universally superior pedagogy. Rather than supporting a one-size-fits-all approach, the results reinforce a more conditional interpretation: active learning is effective only when cognitive demands are carefully regulated. This helps explain why some studies report diminished or inconsistent effects of active learning, particularly in contexts where instructional tasks are poorly structured or excessively complex [16]. By empirically demonstrating that cognitively optimized active learning produces significantly greater learning gains than active learning alone, this study contributes critical nuance to ongoing debates about the efficacy of student-centered pedagogies.

The role of Dual Coding Theory further exposes an underexplored gap in prior research. While many active learning studies emphasize discussion, collaboration, and problem-solving, relatively few examine how the representational format of instructional content influences learning outcomes [33]. The qualitative findings of this study indicate that students consistently benefited from the integration of visual and verbal representations, supporting Paivio's assertion that dual-channel processing enhances comprehension and memory. This contrasts with instructional designs that rely heavily on verbal explanation or text-based discussion, which may inadvertently privilege learners with stronger verbal processing abilities while disadvantaging others [34].

Moreover, the literature often treats visual aids as supplementary or decorative elements rather than as cognitively strategic tools. The present findings challenge this marginalization by showing that visual-verbal integration plays a central role in enabling learners to organize, connect, and retain complex information [35], [36]. Students' reports of improved retention and conceptual clarity suggest that DCT contributes not merely to engagement, but to the structural quality of learning itself. This addresses a persistent contradiction in the

literature, where active learning is praised for engagement benefits but criticized for shallow learning outcomes [11], [37]. The results indicate that when DCT is systematically applied, active learning can indeed foster deep and durable understanding.

A particularly important contribution of this study lies in revealing the synergistic interaction between CLT and DCT within active learning contexts. Prior research has often examined cognitive load management and multimodal representation in isolation, resulting in fragmented insights [8]. The present findings demonstrate that these theories function most effectively when applied together: CLT regulates the amount of cognitive demand, while DCT enhances the quality of cognitive processing. This interaction explains why the experimental group exhibited not only higher test scores but also clearer conceptual integration and more stable retention, outcomes that are rarely achieved through activity-driven pedagogy alone [38].

From a theoretical standpoint, these results also invite a critical re-examination of constructivist learning theory as it is commonly applied. While constructivism emphasizes learners' active role in knowledge construction, it often under-specifies the cognitive constraints under which such construction occurs [39]. This lack of specificity has contributed to instructional designs that prioritize activity without sufficient cognitive guidance [40]. By integrating CLT and DCT, the present study refines constructivist pedagogy through cognitive science, demonstrating that active knowledge construction must be carefully engineered rather than assumed to occur naturally through participation.

In sum, the significance of this study lies in its ability to reconcile conflicting findings in the active learning literature by identifying cognitive-theoretical support as the critical moderating factor. The results show that CLT and DCT are not optional enhancements but essential conditions for effective active learning. By foregrounding cognitive efficiency alongside learner engagement, this research advances a more precise, theory-driven understanding of how active learning should be designed, implemented, and evaluated in higher education. Ultimately, the findings underscore that pedagogical innovation without cognitive grounding risks producing activity without understanding, whereas cognitively informed active learning enables deep, transferable, and enduring learning outcomes.

Learning Implications and Conceptual Framework

Beyond the statistically significant gains in academic performance, the findings of this study carry far-reaching implications for how learning should be designed, theorized, and evaluated in higher education. While much of the existing literature on active learning has focused narrowly on outcome metrics—such as test scores or participation rates—the present study demonstrates that the true impact of active learning lies in its capacity to transform learners' cognitive and motivational experiences when it is grounded in sound cognitive theory [13], [15], [31]. The integration of Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) within active learning does not merely enhance learning outcomes; it fundamentally reshapes how students experience, engage with, and internalize knowledge.

A critical issue in prior active learning research is its tendency to privilege activity over cognition. Numerous studies advocate for collaborative tasks, discussions, and problem-based learning without sufficiently interrogating whether learners possess the cognitive resources required to benefit from such activities [41], [42]. This has resulted in contradictory findings across contexts, with some studies reporting strong gains and others indicating learner frustration, surface learning, or disengagement. The present findings help resolve this contradiction by demonstrating that learning experiences become more manageable, meaningful, and motivating when cognitive demands are deliberately regulated [43]. The qualitative evidence indicates that students perceived the learning process as less overwhelming and more coherent when instructional design accounted for cognitive load, underscoring the necessity of cognitively informed pedagogy.

From the perspective of motivational theory—particularly self-determination theory and expectancy-value theory—this finding is highly significant. Learners are more likely to sustain effort, persistence, and engagement when tasks are perceived as optimally challenging rather than excessively demanding [44]. By reducing unnecessary cognitive load through segmentation, scaffolding, and structured sequencing, CLT enables students to invest cognitive effort productively instead of defensively [45]. Cognitive efficiency, in this sense, functions as a prerequisite for motivation. When learners are not preoccupied with managing confusion or overload, they are more willing to participate, take intellectual risks, and engage deeply with learning tasks [14]. This challenges a common assumption in the literature that motivation is primarily driven by pedagogical novelty or interactivity; instead, the findings suggest that motivation is inseparable from cognitive accessibility.

The reported increases in student engagement and participation also align closely with socio-cognitive and social constructivist theories of learning. Active learning environments are predicated on interaction, dialogue, and collaborative meaning-making; however, such processes are fragile when learners are cognitively overwhelmed [46]. Prior studies have documented cases in which group work devolves into

superficial participation or social loafing, particularly when tasks are poorly structured [39]. The present findings suggest that CLT plays a stabilizing role in social learning contexts by ensuring that cognitive demands remain within manageable limits. When learners are cognitively supported, they are better positioned to contribute meaningfully to discussions, interpret peers' ideas, and co-construct understanding.

In parallel, Dual Coding Theory enhances the quality of these social interactions by providing shared representational resources [31]. Visual-verbal representations function as cognitive anchors that support explanation, negotiation of meaning, and collective sense-making. Rather than relying solely on abstract verbal discourse—which may privilege certain learners over others—dual-coded materials create a common cognitive ground that facilitates inclusive participation [35]. This addresses an often-overlooked limitation in active learning research: the assumption that all learners benefit equally from discussion-based pedagogy. The present findings indicate that representational design is a critical factor in ensuring equitable access to learning within active environments.

At a deeper cognitive level, the integration of CLT and DCT supports more durable learning by strengthening knowledge organization, transfer, and long-term retention [47]. Students' reports of improved recall days after instruction suggest that learning extended beyond short-term performance effects, pointing toward effective schema construction and consolidation in long-term memory [48]. This aligns with information processing theory, which emphasizes that learning quality depends not merely on exposure to information, but on how information is encoded, organized, and integrated with existing knowledge structures. Visual-verbal integration, when combined with controlled cognitive load, promotes elaborative processing and reduces the likelihood of fragmented or inert knowledge.

This finding is particularly significant in light of persistent critiques that active learning may favor engagement at the expense of conceptual depth. By demonstrating that cognitively supported active learning enhances both engagement and retention, the present study challenges this false dichotomy. Engagement and depth are not competing outcomes; rather, they are mutually reinforcing when learning environments are designed in accordance with cognitive principles [49]. This insight contributes to a more nuanced understanding of instructional effectiveness and underscores the need to evaluate learning experiences holistically rather than through isolated outcome measures.

The synthesis of robust quantitative gains with rich qualitative insights provides the empirical foundation for the conceptual framework proposed in this study. Unlike many prior models that treat active learning, cognitive load management, and multimodal instruction as separate or loosely connected elements, the proposed framework positions them as interdependent components within a unified instructional system. Active learning serves as the pedagogical context that situates learners as active constructors of knowledge [7]. Cognitive Load Theory functions as a regulatory mechanism that governs the complexity, sequencing, and structure of learning tasks. Dual Coding Theory operates as a representational mechanism that enhances information processing through coordinated visual and verbal channels.

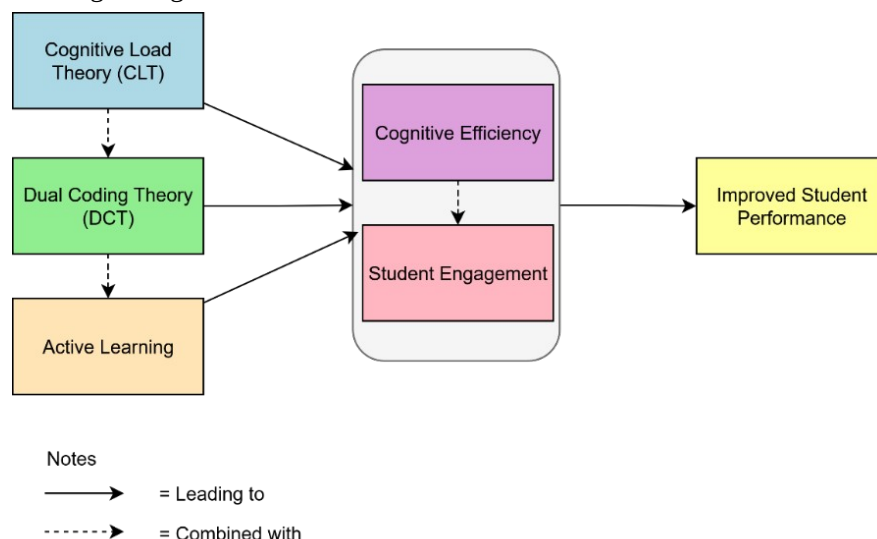


Figure 2. Conceptual model of integrating CLT and DCT within active learning to improve student performance

Source. Data from interviews with informants.

As illustrated in Figure 2, the conceptual model depicts a coherent progression from instructional design to learning processes and, ultimately, to learning outcomes. Active learning strategies, when cognitively optimized through CLT, reduce extraneous cognitive load and enable learners to allocate cognitive resources toward germane processing. Concurrently, DCT strengthens encoding, comprehension, and retrieval by

enriching the representational quality of instructional materials. These cognitive processes foster higher levels of engagement, motivation, and conceptual understanding, which collectively translate into improved academic performance [16], [29]. Importantly, the model emphasizes processual mechanisms rather than treating learning outcomes as isolated endpoints.

The significance of this conceptual framework lies in its explanatory and generative power. It directly addresses a long-standing gap in the literature by clarifying *why* active learning is effective under certain conditions and ineffective under others. By grounding pedagogical practice in cognitive theory, the framework moves beyond descriptive advocacy of active learning toward a mechanistic understanding of instructional effectiveness [8], [50]. For practitioners, the model offers a principled guide for designing learning environments that align instructional activities with learners' cognitive capacities. For researchers, it provides a testable framework for examining specific causal pathways linking instructional design, cognitive processing, motivation, and learning outcomes.

Moreover, the framework invites a re-evaluation of how pedagogical innovation is conceptualized in higher education. Too often, innovation is equated with novelty—new activities, technologies, or formats—without sufficient attention to cognitive consequences. The present model underscores that innovation without cognitive grounding risks producing engagement without understanding. By contrast, cognitively grounded active learning represents a form of sustainable innovation that prioritizes depth, transferability, and long-term learning.

In sum, the proposed conceptual framework advances both theory and practice by positioning cognitive efficiency as the central mechanism through which active learning achieves its educational impact. Figure 2 above thus represents not merely a visual summary of findings, but a theoretically integrated model that synthesizes cognitive, motivational, and pedagogical dimensions of learning. This framework underscores the imperative for higher education to move beyond activity-centered instruction toward cognitively engineered learning designs that ensure engagement results in deep, transferable, and enduring learning outcomes.

Limitations of the Study

Despite the strong empirical and theoretical contributions of this study, several limitations must be acknowledged to provide a balanced interpretation of the findings and to guide future research. Recognizing these limitations is essential not only for transparency but also for situating the proposed conceptual framework within its appropriate scope of applicability.

First, this study was conducted within a single institutional context and involved a relatively limited sample size drawn from two intact classes. Although the quasi-experimental design and statistical analyses provide robust evidence of the effectiveness of integrating Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) within active learning, the findings should be interpreted with caution when generalizing to other educational settings. Variations in institutional culture, disciplinary characteristics, student demographics, and instructional norms may influence how cognitive-theoretically supported active learning functions in practice. Future studies employing multi-institutional or cross-disciplinary samples would be valuable for testing the stability and generalizability of the proposed conceptual framework.

Second, the duration of the instructional intervention represents another limitation. The study primarily examined short- to medium-term learning outcomes, as reflected in post-test performance and students' immediate reflections on their learning experiences. While the qualitative data suggest improvements in retention and conceptual understanding, the study did not include delayed post-tests or longitudinal measures to assess long-term knowledge retention and transfer. Given that one of the central claims of integrating CLT and DCT is the promotion of durable learning, future research should investigate whether these benefits persist over extended periods and across different learning contexts.

Third, although the mixed-methods approach strengthened the validity of the findings, the qualitative data relied on self-reported student perceptions gathered through interviews. While such data provide rich insights into learners' cognitive and motivational experiences, they may be subject to social desirability bias or retrospective rationalization. Students' positive perceptions may also have been influenced by the novelty of the instructional approach rather than solely by its cognitive effectiveness. Triangulating interview data with additional qualitative sources—such as classroom observations, learning analytics, or think-aloud protocols—would allow for a more nuanced examination of cognitive processes during active learning.

Another important limitation concerns the operationalization of cognitive load. While CLT principles were embedded in the instructional design, the study did not directly measure intrinsic, extraneous, or germane cognitive load using standardized cognitive load instruments. As a result, conclusions regarding cognitive load reduction are inferred from learning outcomes and qualitative perceptions rather than from

direct measurement. Future studies could strengthen causal claims by incorporating validated cognitive load scales or physiological measures to more precisely capture learners' cognitive experiences during instruction.

Additionally, this study focused primarily on learning outcomes and learner experiences, with less attention given to instructional feasibility and teacher-related variables. Designing and implementing cognitively optimized active learning requires substantial pedagogical expertise, preparation time, and instructional resources. The effectiveness observed in this study may therefore be influenced by instructor proficiency in applying CLT and DCT principles. Without adequate training or institutional support, instructors may struggle to implement such approaches consistently. Future research should examine the role of teacher cognition, professional development, and institutional conditions in sustaining cognitively grounded active learning practices.

Finally, while the proposed conceptual framework integrates cognitive, motivational, and pedagogical dimensions of learning, it does not explicitly account for individual differences among learners, such as prior knowledge, learning preferences, or self-regulation skills. Prior research suggests that these factors may moderate the effectiveness of active learning and cognitive instructional design. Future studies could extend the framework by examining how learner characteristics interact with CLT- and DCT-informed instruction, thereby refining the model's explanatory and predictive power.

In acknowledging these limitations, it is important to emphasize that they do not diminish the significance of the study's contributions. Rather, they delineate the boundaries within which the findings should be interpreted and highlight promising directions for future inquiry. By addressing these limitations, subsequent research can further validate, refine, and expand the proposed conceptual framework, strengthening its relevance for diverse higher education contexts

CONCLUSION

The results of this study show that the integration of Cognitive Load Theory (CLT) and Dual Coding Theory (DCT) within active learning effectively enhances student performance in higher education. The quasi-experimental findings confirmed that the experimental group achieved higher post-test gains compared to the control group, while qualitative data revealed students' perceptions of reduced cognitive overload, stronger comprehension through visual-verbal representation, and higher motivation to participate in class. These results directly answer the research problem by demonstrating that CLT and DCT not only support but also optimize active learning in both cognitive and affective dimensions.

This study also highlights the urgency of embedding cognitive principles into pedagogical practice. Without such integration, active learning risks being cognitively demanding and less effective, particularly for novice learners. The findings underscore that combining CLT's focus on reducing extraneous load with DCT's dual-channel processing leads to more structured, engaging, and memorable learning experiences. This confirms that theoretically grounded instructional design is essential for sustaining student achievement in the increasingly complex higher education landscape.

Based on these results, it is recommended that educators and curriculum designers adopt CLT and DCT-informed strategies when implementing active learning to maximize both efficiency and engagement. Future research could extend this work by applying the model across different disciplines, larger student populations, and varied cultural contexts to strengthen its generalizability. Furthermore, longitudinal studies are suggested to examine whether the observed improvements in cognitive efficiency and engagement translate into long-term academic success and professional readiness.

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Hopefully this research can make a useful contribution to the development of science and educational practices in the future.

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