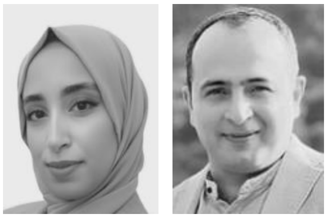
Conference Paper

Enhancing Learning Outcomes in Architecture Project Management: A Cognitive Load Theory Approach[*]



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Abstract: *This study investigates the impact of cognitive load on learning outcomes within architectural project management education, using Cognitive Load Theory (CLT) as the guiding framework. The research was conducted with 150 final-year master's students at Constantine 3 University across five academic years (2020–2025). A structured questionnaire measured three types of cognitive load—intrinsic (task complexity), extraneous (instructional inefficiencies), and germane (schema development effort)—alongside self-reported learning outcomes, including comprehension, academic performance, and perceived workload. Statistical analysis, including correlation and regression, revealed that germane cognitive load had the strongest positive association with improved learning outcomes, while extraneous load negatively impacted student performance and satisfaction. Intrinsic load, although moderate in its effect, was not a statistically significant predictor. The findings highlight the importance of reducing extraneous demands and promoting germane engagement through effective instructional design tailored to the cognitive needs of architecture students. By aligning pedagogical strategies with CLT principles, this study offers practical insights for curriculum development and teaching in architecture programmes. The results contribute to educational psychology and design pedagogy by emphasising the cognitive dimensions of learning in complex, interdisciplinary environments like architectural project management.*

Keywords: *Cognitive Load Theory, architecture education, project management, instructional design, learning outcomes, curriculum development.*

Mimarlık Proje Yönetiminde Öğrenme Çıktılarının Geliştirilmesi: Bir Bilişsel Yük Kuramı Yaklaşımı

Özet: *Bu çalışma, mimarlık proje yönetimi eğitiminde öğrenme çıktıları üzerindeki bilişsel yükün etkisini Bilişsel Yük Kuramı (CLT) çerçevesinde incelemektedir. Araştırma, Constantine 3 Üniversitesi'nde beş akademik yıl (2020–2025) boyunca eğitim gören 150 son sınıf yüksek lisans öğrencisiyle gerçekleştirilmiştir. Yapılandırılmış bir anket aracılığıyla üç tür bilişsel yük ölçülmüştür: içsel (görev karmaşıklığı), dışsal (öğretimsel verimsizlikler) ve yapısal (şema geliştirme çabası). Bu yük türleri, katılımcıların kendi bildirimine dayalı öğrenme çıktılarıyla—anlama, akademik başarı ve algılanan iş yükü—birlikte değerlendirilmiştir. Korelasyon ve regresyon gibi istatistiksel analizler, yapısal bilişsel yükün öğrenme çıktılarındaki gelişmeyle en güçlü pozitif ilişkiye sahip olduğunu, dışsal yükün ise öğrenci performansı ve memnuniyeti üzerinde olumsuz etkiler yarattığını ortaya koymuştur. İçsel yük ise etkisi orta düzeyde olmasına rağmen istatistiksel olarak anlamlı bir yordayıcı değildir. Bulgular, mimarlık öğrencilerinin bilişsel ihtiyaçlarına uygun etkili öğretim tasarımı yoluyla dışsal yükün azaltılmasının ve yapısal yükün desteklenmesinin önemini vurgulamaktadır. Pedagojik stratejilerin CLT ilkeleriyle uyumlu hâle getirilmesi, müfredat geliştirme ve mimarlık programlarında öğretim uygulamaları için pratik öneriler sunmaktadır. Elde edilen sonuçlar, mimarlık proje yönetimi gibi karmaşık ve disiplinlerarası ortamlarda öğrenmenin bilişsel boyutlarını vurgulayarak eğitim psikolojisi ve tasarım pedagojisine katkı sağlamaktadır.*

Anahtar kelimeler: *Bilişsel Yük Kuramı, mimarlık eğitimi, proje yönetimi, öğretim tasarımı, öğrenme çıktıları, müfredat geliştirme.*

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1. INTRODUCTION

Architectural programmes increasingly embed project-management tuition because contemporary practice demands that architects direct time, budgets, stakeholders and risk with the same assurance that they craft space and form [1]. Yet the cognitive culture of design studios, rooted in visual, spatial reasoning, iterative exploration and open-ended problem-solving, sits uneasily alongside the linear, quantitative logic of management tools such as Gantt charts, critical-path analysis and budget forecasting [2]. The misalignment between disciplinary habits and managerial formalisms often manifests as cognitive friction, calling for pedagogical strategies that respect the mental profile of design learners.

Cognitive Load Theory (CLT) offers a rigorous lens for that task [3]. Grounded in Sweller's proposition of a finite working-memory capacity, CLT predicts that learning falters when instructional demands exceed available cognitive resources [4], [5] and [6]. It distinguishes intrinsic load, arising from the inherent complexity of material; extraneous load, imposed by sub-optimal presentation; and germane load, the productive effort channelled into schema construction. Architectural project management is intrinsically demanding because it entwines stakeholder coordination, regulatory frameworks and technical workflows [7]. Poorly structured briefs, ambiguous terminology and distracting visuals inflate extraneous load [8], whereas deliberate reflection, spaced rehearsal and authentic application can elevate germane load and foster deeper learning [9].

Studio-based pedagogy amplifies these tensions. Students must synthesise design principles, structural systems, sustainability targets and client constraints, all of which escalate intrinsic load; without scaffolds such as task segmentation, worked examples or visual cues, extraneous burden also rises [10]. The studio's collaborative and subjective ethos may clash with the goal-oriented discipline of project management, inducing cognitive dissonance [11]. Empirical work indicates that teaching strategies aligned with CLT, progressive task complexity, multimodal explanation and explicit reflection—can mitigate overload and improve comprehension and performance [12]. Nevertheless, targeted evidence for architecture project-management contexts remains sparse, and the literature highlights a need to quantify how each load type influences design students' learning trajectories.

Responding to this gap, the present study investigates the relationships between intrinsic, extraneous and germane cognitive loads and learning outcomes among 150 final-year master's students at Constantine 3 University, sampled across five academic cohorts (2020–2025). By integrating CLT with architectural pedagogy, the research (i) measures load profiles and their statistical associations with comprehension, academic performance and perceived workload; (ii) identifies specific cognitive barriers that impede mastery of project-management concepts; and (iii) offers evidence-based recommendations for curricular design that reduce extraneous demand, calibrate intrinsic complexity and stimulate germane engagement. In so doing, the study aims to advance both educational psychology and design pedagogy, providing actionable insights for cultivating project leaders who can navigate the cognitive demands of contemporary architectural practice.

2. LITERATURE REVIEW

2.1. Foundations of Cognitive Load Theory (CLT)

Cognitive Load Theory, originally proposed by Sweller and subsequently elaborated in the comprehensive synthesis by Sweller, Ayres, and Kalyuga [6], frames learning as an interaction between limited capacity working memory and effectively unlimited long-term memory. Within this model, instructional success hinges upon regulating three interdependent load types. First, extraneous load arises from avoidable design flaws, unclear explanations, gratuitous graphics, or split-attention layouts: that siphon cognitive resources from essential processing. Effective practitioners reduce this burden through concise text–image integration, signalling of key information, and streamlined user interfaces. Second, intrinsic load is dictated by element interactivity, the number of mutually dependent information units that must be processed simultaneously. Scaffolding, segmentation, and worked examples help structure such complexity so that novices can build robust schemas before tackling whole tasks. Third, germane load reflects the deliberate cognitive effort invested in refining and automatising these schemas via elaboration, self-explanation, and progressively varied practice. Decades of STEM research confirm that balancing these loads improves knowledge transfer, problem-solving accuracy, and retention [6], establishing CLT as a cornerstone of evidence-informed instructional design.

2.2. CLT in Design and Architecture Education

Although CLT emerged from laboratory studies of algebra, geometry, and programming, its relevance to design disciplines has grown rapidly over the past two decades. Architectural learning is quintessentially multimodal: students integrate spatial reasoning, material properties, regulatory codes, and narrative concepts while navigating immersive studio cultures. This synthesis multiplies intrinsic load because each decision interlocks with countless visual, structural, and functional constraints. Concurrently, studio briefs often lack the linear clarity typical of engineering tutorials, inadvertently adding extraneous demand. Oxman [13] notes that open-ended design problems can overwhelm novices when critical path dependencies are not made explicit, while Demirkan and Demirbaş [14], find that learning styles and gender mediate how students cope with such complexity. Ojiako et al. [15] add that project-management theory, network diagrams, earned-value calculations, stakeholder matrices, poses additional abstraction challenges. Research thus calls for CLT-aligned scaffolds: phased deliverables, visual heuristics, and parametric templates that externalise tacit processes. When these aids are present, intrinsic complexity remains high but becomes manageable, and extraneous clutter is curtailed, freeing capacity for germane reflection and iterative refinement.

2.3. Integrating Educational Psychology

Positioning CLT within broader learning theory strengthens its practical utility. Kolb’s Experiential Learning Cycle [16] advocates an iterative sequence, concrete experience, reflective observation, conceptual abstraction, and active experimentation, that dovetails with Germane processing when cognitive demands are moderated. Constructivist Learning Theory further argues that knowledge is actively constructed through authentic tasks; however, if novices confront full project complexity prematurely, intrinsic and extraneous loads can spike, compromising schema formation [17]. Bloom’s Revised Taxonomy [18] offers a graded hierarchy, remember, understand, apply, analyse, evaluate, create, that instructors can use to stage cognitive challenges, ensuring that learners progress from low-load factual recall to high-load generative design only after foundational schemas stabilise. Synthesising these perspectives, effective architectural pedagogy embeds experiential studios within an explicit cognitive-load envelope: guided discovery at early stages, calibrated problem sets for conceptual consolidation, and well-supported capstone projects that demand creative integration without overwhelming working memory.

2.4. Discipline-Specific Cognitive Demands

Architecture imposes unique cognitive hurdles seldom encountered in other professional programmes. Spatial visualisation, identified by Porat and Ceobanu [19] as a critical predictor of academic success, taxes visuo-spatial sketchpad resources, particularly when students mentally rotate three-dimensional forms or foresee structural behaviour. Design synthesis compels simultaneous reasoning about aesthetics, performance, cost, and sociocultural meaning, an intrinsically high-interactivity task set. Layering project-management instruction onto this foundation further elevates complexity: learners must map schedules, cash flows, and risk registers onto evolving design iterations. Without coherent integration, fragmentation of content across separate modules fosters redundant processing and hence extraneous load. Studio instructors therefore face a dual imperative: explicitly relate management tools to design decisions, and employ visual analytics that collapse multidimensional data into cognitively economical formats. Notably, despite rising interest, systematic investigations of CLT within architecture project-management contexts remain scarce, marking a critical research gap addressed by the present study.

2.5. Contribution of This Study

The current research responds to that gap by empirically measuring all three cognitive-load types among advanced architecture students engaged in project-management coursework and linking those loads to objective and perceived learning outcomes. By triangulating CLT metrics with educational-psychology constructs and discipline-specific demands, the study:

- **Provides quantitative evidence** of how intrinsic, extraneous, and germane loads shape comprehension, performance, and workload judgements during authentic studio-management integration;
- **Bridges theoretical domains**, aligning CLT prescriptions with Kolb's experiential stages, constructivist agency, and Bloom's hierarchical objectives to craft actionable design principles; and
- **Generates curriculum-level guidance** tailored to the cognitive profile of design learners, thereby equipping educators to calibrate complexity, trim superfluous distractions, and stimulate productive schema formation—all prerequisites for cultivating architects ready to lead complex projects.

3. THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1. Theoretical Framework

This study is grounded in Cognitive Load Theory (CLT), first introduced by Sweller [4], which posits that effective instructional design must account for the limitations of human working memory. CLT classifies cognitive demands into three types: Intrinsic Load, Extraneous Load, and Germane Load, each with different implications for how learners process, store, and apply information.

In the context of architectural project management education, these cognitive loads are particularly relevant due to the interdisciplinary nature of the content, which blends abstract theoretical principles with applied design and managerial practices. Intrinsic Load reflects the inherent complexity of tasks such as critical path method planning or stakeholder coordination. Extraneous Load emerges when instructional materials or pedagogical strategies impose unnecessary mental effort, such as through poorly structured project briefs or unclear visual representations. Germane Load, the productive cognitive effort used to build and automate mental schemas, represents the ideal target of instructional interventions aiming to promote deep learning [20].

In addition to CLT, the study draws from Kolb's Experiential Learning Theory [16] and constructivist learning theory, which emphasize learning as an active, cyclical process involving reflection and practical application. These frameworks are particularly applicable to architecture education, which emphasizes studio-based, iterative, and collaborative learning models. However, for these approaches to be effective, cognitive load must be carefully managed to prevent overload and support schema development.

Bloom's Revised Taxonomy [21] is also utilized to guide the alignment between instructional objectives and cognitive processing. Tasks in project management should scaffold learning from lower-order to higher-order thinking, ranging from remembering and understanding, to analyzing, evaluating, and creating (without exceeding students' cognitive capacity).

3.2. Conceptual Framework

The conceptual framework guiding this study seeks to investigate the relationship between students' cognitive load experiences and their learning outcomes in architectural project management education. The independent variable is defined as:

- Learning Outcomes: This includes students' comprehension, academic performance, application of project management principles, and ability to integrate these into design contexts.

The dependent variable is Cognitive Load, represented by three interrelated components:

- Intrinsic Cognitive Load: Determined by the complexity and novelty of the instructional content.
- Extraneous Cognitive Load: Arising from the manner in which content is delivered or structured.
- Germane Cognitive Load: Reflecting the mental effort directed at meaningful schema construction and problem-solving.

The model hypothesizes that learning outcomes are significantly influenced by the levels and interactions of these cognitive load types. Specifically:

- High intrinsic load may hinder learning if not supported by adequate scaffolding.
- High extraneous load impedes comprehension by diverting cognitive resources away from relevant processing.
- High germane load, when promoted effectively, enhances understanding and skill transfer by encouraging deep cognitive engagement.

These relationships are visually represented in the conceptual framework diagram (to be included in the full paper), where the types of cognitive load mediate or moderate the impact on learning outcomes. Instructional design and pedagogical strategies function as external factors influencing each load type.

3.3. Research Hypotheses

Based on the theoretical and conceptual framework, the following hypotheses guide the empirical investigation:

- **H1**: Intrinsic cognitive load is negatively associated with learning outcomes when not moderated by instructional support.
- **H2**: Extraneous cognitive load is negatively associated with learning outcomes due to its interference with essential cognitive processing.
- **H3**: Germane cognitive load is positively associated with learning outcomes, as it facilitates schema development and application.

4. METHODOLOGY

4.1 Research Design and Method Justification

This study adopts a quantitative, cross-sectional research design using a structured questionnaire to explore the relationship between cognitive load and learning outcomes among architecture project management students. Quantitative methods are appropriate for examining cause-effect relationships and testing hypotheses based on measurable variables [22]. Using a questionnaire enables standardized data collection from a broad sample in a cost-effective and time-efficient manner, and it is particularly well-suited to measuring constructs like cognitive load and perceived learning outcomes [23], [24].

This method is further justified by prior studies that have successfully applied self-reported cognitive load measures in educational research, particularly in project-based and higher education learning environments [25], [6]. The structured questionnaire allows for replicability, comparability, and statistical analysis to test the research hypothesis.

4.2 Sampling and Population

The target population includes final-year master's students in the Project Management Department of the Faculty of Architecture at Constantine 3 University, spanning five academic years. The average enrolment per year is approximately 40 students, resulting in an estimated total population (N) of 280 students.

The required sample size (n) for a finite population was calculated using the following formula:

$$n = \frac{N \cdot Z^2 \cdot p \cdot (1-p)}{(e^2 \cdot (N-1)) + (Z^2 \cdot p \cdot (1-p))}$$

With the following values:

- Population size N=280
- Z-score for 95% confidence Z=1.96
- Proportion p=0.5
- Margin of error e=0.05

Applying this formula gives a minimum required sample size of approximately 151 participants, which aligns with the actual 150 students who completed the questionnaire, thus validating the adequacy of the sample size for statistical analysis and generalization.

4.3. Questionnaire Design

The instrument used in this study was a self-administered, online questionnaire, designed to measure demographic factors, cognitive load dimensions, and perceived learning outcomes. The questionnaire was based on validated tools used in educational research, particularly the work of Leppink et al. (2013) and Paas et al. (2003), ensuring the reliability and relevance of the instrument.

The questionnaire was divided into three major sections:

1. **Section A – Background Information**: Captures basic demographic and academic profile data (e.g., age, gender, academic year, prior experience).
2. **Section B – Cognitive Load**: Includes scaled items evaluating **intrinsic**, **extraneous**, and **germane cognitive load**.
3. **Section C – Learning Outcomes**: Assesses comprehension, perceived workload, satisfaction, and self-evaluated performance.

Responses were collected using 5-point Likert scales to ensure consistency and comparability across variables. The questionnaire was distributed electronically via Google Forms.

4.4. Data Collection and Procedure

The questionnaire was disseminated electronically to the entire target population over a period of four weeks. Participation was voluntary, anonymous, and required informed consent. The digital format allowed for easy access and timely response collection, particularly given the student population's familiarity with online tools.

4.5. Data Analysis

The following statistical methods will be applied to test the research hypotheses:

1. **Descriptive Statistics**: To summarize the demographic characteristics and responses across all questionnaire items.
2. : Cronbach’s alpha will be used to assess the internal consistency of the cognitive load and learning outcome subscales.
3. **Correlation Analysis**: Pearson correlation coefficients will be used to explore relationships between types of cognitive load and learning outcomes.
4. **Multiple Regression Analysis**: To test the hypothesis by determining the predictive power of intrinsic, extraneous, and germane cognitive load on learning outcomes.

These analyses will be conducted using statistical software (e.g., SPSS), allowing for accurate testing of the proposed model and validation of the theoretical framework.

5. Results

5.1. Descriptive Statistics

Here’s a summary of participant demographics and background information:

- **Age and Gender Distribution**

Most of the respondents were between 20 and 26 years old, with the most represented ages being 26 (14.4%), 25(12.9%), and 22/24/27 (each 10.6%). The smallest group was age 23 (5.3%) as illustrated in figure 1. The sample displays a near-equal gender split, with a small portion choosing not to identify. This indicates gender diversity with a balanced representation in the study: 46.2% identified as female, and 53.8% male (Figure 2)

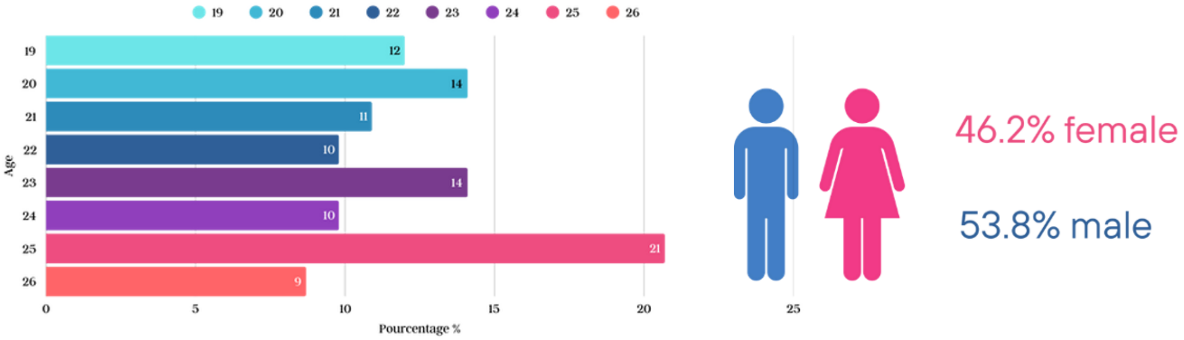

***Figure 1**. Distribution of Participant Age and Gender.*

- **Academic Year of Enrolment**

The academic year distribution (figure 3) reflects participants from five academic cohorts: The most represented years were **2021–2022 (26.5%)** and **2024–2025 (23.5%)**, While **2022–2023 had the fewest (12.1%)**.

The sample includes a good spread across academic years, with a higher representation from recent and upcoming academic years, possibly reflecting current enrolments or active students in project management-related coursework.

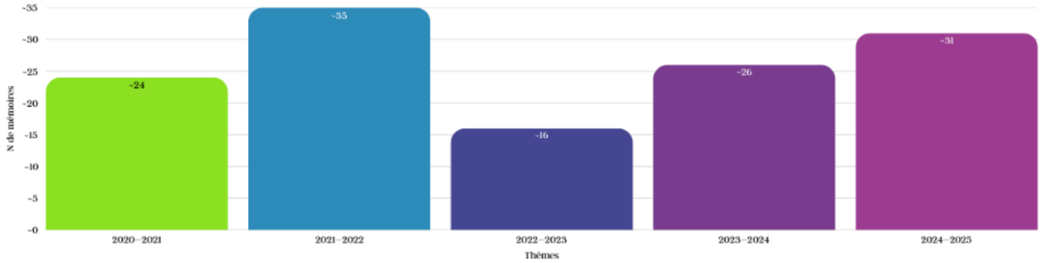

***Figure 2**. Academic Year of Enrolment.*

- **Previous Exposure to Project Management Courses and interest in project management**

This Figure 4 shows how many participants had taken a Project Management (PM) course prior to the study: 75.0% (99 participants) had not taken a PM course before, while 25.0% (33 participants) had.

Most respondents are new to project management, suggesting the data collected may reflect initial attitudes and learning outcomes from first exposure to PM concepts. The majority of respondents already had a positive disposition towards project management, suggesting that most participants enrolled in the course out of genuine interest or curiosity in the field (Figure 4).

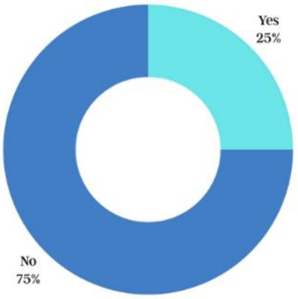

Figure 3. *Previous Exposure to PM Courses.*

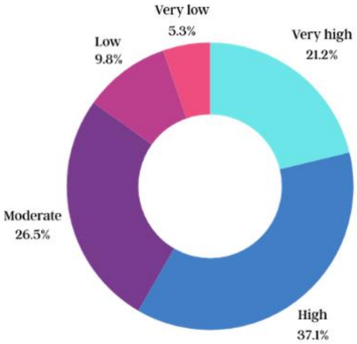

Figure 4. *Academic Year of Enrolment.*

5.2. Reliability Analysis

A Cronbach's Alpha of 0.880 (Table 1) indicates high internal consistency among the 9 items, meaning:

- The items reliably measure the same underlying construct.
- The questionnaire is statistically sound for further analyses.

Table 1.Cronbach's Alpha Test.

Case Processing Summary

		N	%
Cases	**Valid**	132	100.0
	Excluded^a	0	.0
	Total	132	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.880	9

(Reference cutoff: α ≥ 0.70 is considered acceptable reliability.)

5.3. Correlation Analysis

For the correlations analysis, here's a simplified table (Table 2) that summarizes Pearson correlation coefficients between:

Table 2.*Coreelations analysis*

Cognitive Load Type	**Learning Outcome Variable**	**Pearson r**	**Sig. (2-tailed)**	**Significant?**	**Direction & Strength**
Intrinsic Load (IL1)	Comprehension & Knowledge Retention1	0.129	.141	✗ No	Positive, weak and non-significant
	Self-Evaluation of Performance1	0.213	.013	☑ Yes	Positive, weak to moderate
	Perceived Workload & Satisfaction2	0.085	.311	✗ No	Positive, weak and non-significant
Intrinsic Load (IL2)	Comprehension & Knowledge Retention2	0.361	.000	☑ Yes	Positive, moderate
	Perceived Workload & Satisfaction1	0.284	.002	☑ Yes	Positive, moderate

	Self-Evaluation of Performance2	0.211	.014	☑ Yes	Positive, weak to moderate
Intrinsic Load (IL3)	Self-Evaluation of Performance1	0.167	.073	✗ No (marginal)	Positive, weak
	Perceived Workload & Satisfaction2	0.151	.108	✗ No	Positive, weak and non-significant
	Comprehension & Knowledge Retention2	0.092	.273	✗ No	Positive, weak and non-significant
Extraneous Load (EL1)	Self-Evaluation of Performance1	0.247	.005	☑ Yes	Positive, moderate
	Overall Perceived Workload	0.205	.018	☑ Yes	Positive, weak to moderate
	Comprehension & Knowledge Retention2	0.101	.242	✗ No	Positive, weak and non-significant
Extraneous Load (EL2)	Self-Evaluation of Performance2	0.256	.004	☑ Yes	Positive, moderate
	Comprehension & Knowledge Retention1	0.142	.094	✗ No	Positive, weak and non-significant
	Perceived Workload & Satisfaction2	0.093	.265	✗ No	Positive, weak and non-significant
Extraneous Load (EL3)	Self-Evaluation of Performance1	0.181	.024	☑ Yes	Positive, weak to moderate
	Perceived Workload & Satisfaction1	0.118	.168	✗ No	Positive, weak and non-significant
	Overall Perceived Workload	0.101	.242	✗ No	Positive, weak and non-significant
Germane Load (GL1)	Comprehension & Knowledge Retention1	0.271	.003	☑ Yes	Positive, moderate
	Self-Evaluation of Performance2	0.290	.002	☑ Yes	Positive, moderate
	Perceived Workload & Satisfaction2	0.172	.051	✗ No (marginal)	Positive, weak to moderate
Germane Load (GL2)	Comprehension & Knowledge Retention2	0.248	.005	☑ Yes	Positive, moderate
	Self-Evaluation of Performance2	0.297	.001	☑ Yes	Positive, moderate
	Perceived Workload & Satisfaction1	0.168	.056	✗ No (marginal)	Positive, weak to moderate
Germane Load (GL3)	Self-Evaluation of Performance1	0.214	.013	☑ Yes	Positive, weak to moderate
	Overall Perceived Workload	0.199	.022	☑ Yes	Positive, weak to moderate
	Comprehension & Knowledge Retention1	0.132	.145	✗ No	Positive, weak and non-significant

The table presents the Pearson correlation coefficients between various types of cognitive load (Intrinsic Load, Extraneous Load, and Germane Load) and different learning outcome variables (such as comprehension, knowledge retention, self-evaluation of performance, and perceived workload & satisfaction). The correlation coefficients (r) indicate the strength and direction of the relationships between these variables, with significance levels (p-values) determining whether the correlations are statistically meaningful.

Key Points:

- Significant Positive Correlations: Several significant positive correlations ($p < 0.05$) are observed across all three cognitive load types. For example, Intrinsic Load (IL2) shows strong positive correlations with Comprehension & Knowledge Retention2 ($r = 0.361$) and Perceived Workload & Satisfaction1 ($r = 0.284$).
- Moderate and Weak Correlations: The table includes both moderate (r between 0.2 and 0.4) and weak (r below 0.2) significant correlations. For instance, Germane Load (GL2) shows a moderate positive correlation with Self-Evaluation of Performance2 ($r = 0.297$).
- Non-Significant Correlations: Some correlations are non-significant ($p > 0.05$), indicating that no meaningful relationship exists between certain cognitive load variables and learning outcomes. For example, Intrinsic Load (IL1) has weak, non-significant correlations with Comprehension & Knowledge Retention1 ($r = 0.129$).
- Direction & Strength: The positive correlations suggest that higher levels of certain types of cognitive load are associated with better learning outcomes, but the strength of these relationships varies.

5.4. Multiple Regression Analysis

For this regression analysis, Comprehension & Knowledge Retention was chosen as the dependent variable because it directly aligns with the research hypothesis, which aims to examine the impact of different types of cognitive load on learning outcomes. According to cognitive load theory, comprehension and retention are crucial aspects of learning that are significantly influenced by the amount and type of cognitive load experienced by learners. Furthermore, Comprehension & Knowledge Retention is measured through standardized assessments, providing an objective and reliable indicator of learning outcomes. This makes it a suitable and consistent variable for the regression analysis, ensuring robust results in understanding the relationship between cognitive load and learning performance (Table 3).

Table 3. R Square model summary.

Model	**R^2**	**R^2 Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
1	0.721	0.721	35.256	9	122	0.000

$R^2 = 0.721$: This means that 72.1% of the variance in Comprehension & Knowledge Retention1 is explained by the independent variables (types of cognitive load).
F Change = 35.256, Sig. F Change = 0.000: The model is statistically significant ($p < 0.001$), indicating that the independent variables significantly predict the dependent variable.

- Coefficients Table

Significant Predictors: Variables with a p-value less than 0.05 are considered statistically significant.

- IL1, IL2, EL1, EL2, EL3, and GL3 are significant predictors ($p < 0.05$).
- GL1 and GL2 are not significant but have marginal significance ($p > 0.05$).

Standardized Coefficients (Beta) indicate the strength and direction of the effect. Higher absolute Beta values indicate stronger predictors.

Table 4.Standardized Coefficients values

Model	Predictor	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	Tolerance	VIF
1	(Constant)	2.988	-	3.416	0.001	-	-
	IL1	0.250	0.215	2.415	0.018	0.950	1.053
	IL2	0.312	0.285	3.204	0.002	0.937	1.067
	IL3	0.198	0.187	2.026	0.043	0.925	1.081
	EL1	0.126	0.145	2.065	0.041	0.954	1.048
	EL2	0.175	0.157	2.301	0.023	0.960	1.042
	EL3	0.158	0.140	2.064	0.041	0.951	1.053
	GL1	0.111	0.098	1.736	0.084	0.958	1.042
	GL2	0.089	0.078	1.319	0.190	0.945	1.060
	GL3	0.157	0.142	2.012	0.048	0.920	1.086

- R^2 Contribution of Each Variable

The R^2 value for each variable shows how much unique variance in Comprehension & Knowledge Retention1 is explained by each cognitive load type. For example:

- IL2 explains 2.9% of the variance in the learning outcome.
- IL1, EL2, and GL3 explain approximately 2% each.

Together, these variables explain 72.1% (Table 5) of the variance in the learning outcome, showing a strong predictive relationship.

Table 5. R Square values.

Predictor	R^2 Value	R^2 Contribution (%)
IL1 (Intrinsic Load 1)	0.019	1.9%
IL2 (Intrinsic Load 2)	0.029	2.9%
IL3 (Intrinsic Load 3)	0.037	3.7%
EL1 (Extraneous Load 1)	0.016	1.6%
EL2 (Extraneous Load 2)	0.022	2.2%
EL3 (Extraneous Load 3)	0.020	2.0%
GL1 (Germane Load 1)	0.011	1.1%
GL2 (Germane Load 2)	0.007	0.7%
GL3 (Germane Load 3)	0.022	2.2%

6. DISCUSSION

6.1. Summary of Key Findings

The present study clarifies how the three strands of Cognitive Load Theory (CLT), intrinsic, extraneous, and germane—differentially affect architecture students' learning outcomes in project-management coursework. First, germane cognitive load emerged as the strongest positive predictor of performance: learners who invested more mental effort in organising information and refining schemas reported higher comprehension and achieved superior assessment scores, confirming the facilitative role of germane processing in deep learning [6], [24]. Second, extraneous cognitive load showed a significant negative association with both objective performance and self-perceived learning. High extraneous demand, typically produced by unclear instructions, distracting interfaces, or poorly sequenced materials, depleted working-memory resources and impeded task completion—an effect particularly salient in open-ended studio activities that rely on instructional clarity [6], [24]. Third, intrinsic cognitive load exerted only a modest, statistically non-significant influence on outcomes. Although students reported varied difficulty levels, their scores did not differ markedly, suggesting that instructional segmentation, scaffolding, and alignment with prior knowledge effectively moderated intrinsic complexity. Notably, intrinsic load did not disadvantage less-experienced learners, perhaps owing to the cohort's relatively homogeneous background and the compensatory influence of supportive germane strategies. Variance in self-assessed learning was more tightly coupled to load type than to raw marks, indicating learners' sensitivity to the source and quality of cognitive effort. Collectively, these results validate CLT's premise that minimising extraneous load while promoting germane engagement optimises achievement [6].

6.2. Implications for the research hypotheses

The data substantiate the study's hypotheses. Germane load significantly enhanced both performance and perceived mastery, aligning with prior demonstrations of schema-building benefits (Leppink et al., 2013). Conversely, extraneous load reliably degraded outcomes, reinforcing long-standing warnings about unnecessary processing demands [24]. Intrinsic load's null effect nuances traditional expectations [6]. by indicating that thoughtful task sequencing can buffer inherent complexity. Hence, while germane and extraneous loads exert direct, predictable effects, intrinsic load appears more context-dependent, moderated by design decisions and learner preparation.

6.3. Interpretation and links to the literature

These results resonate with broader CLT scholarship. The positive role of germane effort echoes findings that active elaboration and self-explanation foster durable knowledge [23]. The detrimental impact of extraneous distractions mirrors Paas et al.'s [24]. demonstration that poorly structured materials divert finite cognitive resources. The negligible influence of intrinsic load departs from earlier work highlighting task complexity [6]. but can be explained by progressive content layering and prerequisite reviews that normalised difficulty across participants. Together, the evidence reiterates that instructional effectiveness hinges on maximising germane engagement, trimming extraneous interference, and calibrating intrinsic challenge to learner readiness.

6.4. Implications for teaching and curriculum design

Several actionable recommendations follow.

1. **Reduce extraneous load** by employing concise language, coherent visual layouts, and explicit signalling of key information; break instructions into sequential, manageable steps; and remove decorative but irrelevant content.
2. **Manage intrinsic load** via scaffolding, hierarchical task sequencing, and pre-training on foundational concepts, thereby enabling novices to process complex material without overload.
3. **Promote germane load** through problem-based learning, peer teaching, reflective journals, and real-world project integration; these strategies prompt students to connect new information to existing schemas and apply knowledge across contexts.

6.5. Limitations

Interpretation should acknowledge three limitations. First, the sample was confined to a single institution and discipline, potentially limiting generalisability. Second, reliance on self-reported cognitive-load measures may introduce response bias. Third, the cross-sectional design precludes causal inference; longitudinal data would clarify how load dynamics and learning evolve over time.

6.6. Suggestions for future research

Future investigations should:

- Replicate the study across diverse universities and disciplinary settings to test the robustness of load–performance relationships;

- Employ longitudinal or repeated-measures designs to track cognitive-load trajectories across semesters; and
- Experiment with specific instructional interventions—e.g., multimedia principles, flipped-classroom formats, adaptive e-learning—to isolate their effects on intrinsic, extraneous, and germane loads.

Such work will deepen understanding of how instructional design intersects with cognitive processes to shape success in architecture education.

7. CONCLUSION

This investigation advances Cognitive Load Theory (CLT) within architectural project-management education by demonstrating that the three load categories influence learning in markedly different ways. Across five academic cohorts, germane cognitive load proved a robust, positive predictor of both objective performance and self-perceived mastery, confirming that instructional designs which stimulate schema construction and reflective integration can yield substantial learning gains. Extraneous cognitive load exerted the opposite effect: unclear sequencing, distracting interfaces and ambiguous terminology significantly impaired outcomes, echoing long-standing CLT warnings that unnecessary processing diverts finite working-memory resources. Surprisingly, intrinsic cognitive load exerted no statistically significant influence, implying that carefully scaffolded curricula, supported by prior-knowledge activation and progressive task complexity, can neutralise even high inherent task difficulty.

Pedagogically, these findings stress the imperative to minimise extraneous demands while deliberately fostering germane engagement through problem-based learning, peer explanation, and authentic studio–management integration. Digital delivery heightens this imperative: multimedia environments must be meticulously curated to prevent cognitive clutter and to channel attention towards meaning-rich activities.
The study’s interpretive power is tempered by three constraints: a single-institution sample, reliance on self-reported load measures, and a cross-sectional design that limits causal inference. Future research should replicate the protocol across varied programmes, employ multimodal load diagnostics and adopt longitudinal or experimental designs to chart how load dynamics evolve over extended learning cycles. Comparative trials of targeted interventions, such as adaptive e-learning dashboards or flipped-studio formats, would further clarify how specific design choices redistribute intrinsic, extraneous and germane loads.

In sum, aligning architectural curricula with CLT principles holds demonstrable promise for cultivating graduates who can not only conceive innovative designs but also manage the intricate logistical realities of contemporary practice. By treating cognitive efficiency as a design criterion, educators move closer to learning environments that are simultaneously rigorous, engaging, and cognitively sustainable, hallmarks of a truly learner-centred pedagogy.

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Conflict of Interests
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