

# *The Effectiveness of “Understanding by Design” Pedagogical Service on Sixth-Grade Students’ Cognitive Load*

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## **A**bstract

*The growing complexity of instructional materials in elementary science education may impose excessive cognitive load on learners and hinder meaningful learning. Therefore, identifying instructional approaches that effectively manage students’ cognitive load has become an important concern in educational research. The present study investigated the effectiveness of the Understanding by Design (UbD) framework in reducing the cognitive load of sixth-grade students in science. This quasi-experimental study was conducted during the fall semester of the 2022–2023 academic year in Shabestar, Iran. Sixty sixth-grade students participated and were randomly assigned to an experimental group (n = 30) and a control group (n = 30). The experimental group received science instruction designed according to the UbD framework, while the control group was taught using conventional instructional methods. Students’ cognitive load was measured using the PASS Cognitive Load Questionnaire. The collected data were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics through univariate analysis of covariance (ANCOVA) in SPSS version 25. The findings indicated that UbD-based instruction significantly reduced students’ cognitive load compared with traditional teaching methods. These results suggest that aligning learning objectives, assessment evidence, and instructional activities within the UbD framework can facilitate more efficient information processing, reduce unnecessary mental effort, and ultimately enhance the quality and effectiveness of learning.*

## **K**eywords

*Understanding by Design, Understanding by Design Curriculum, Cognitive Load.*

## Introduction

The rapid transformations of the twenty-first century have fundamentally reshaped expectations of teaching and learning. Contemporary educational systems increasingly require teachers to assume roles that extend beyond the traditional function of knowledge transmission. In addition to teaching, teachers are now expected to act as designers of learning environments capable of structuring meaningful and coherent learning experiences (Aspandi & Muttaqin, 2025; Andrews, 2011; Penuel & Gallagher, 2009). According to the views of educational psychology theorists, in addition to cognitive and emotional prerequisites, learners' mastery of appropriate learning strategies and their correct use are essential requirements of the learning process (Masrabadi & Erfani Adab, 2014). Recent research further emphasizes that the ability to design purposeful learning experiences constitutes a core professional competency for teachers in modern education (Penuel & Gallagher, 2009; Suguraliyeva et al., 2026).

Within this perspective, instructional design competence has become a core professional skill, enabling teachers to organize curriculum, assessment, and instructional activities in ways that support deeper learning. One of the major goals of current educational reforms is the shift from emphasizing lower-order thinking skills toward fostering higher-order thinking skills (Gloria et al., 2019; Mahbub & Beedle, 2025). Corvo (2014) argues that meaningful reform in teaching and learning requires a fundamental reorientation of educational objectives toward complex cognitive processes such as analysis, evaluation, and understanding. Among these, understanding is widely considered a central indicator of higher-order thinking. Unlike factual knowledge, understanding involves grasping meaning, relationships, and the ability to apply knowledge in new situations (Gloria et al., 2019). Therefore, given the importance and significance of understanding, teachers are expected not only to teach content in their instructional processes but also to employ strategies that foster the development of higher-order thinking skills (Fry et al., 2009; Siregar, 2025).

However, a considerable body of research indicates that classroom practices often remain focused on content coverage and memorization rather than conceptual understanding. Studies have reported that many teachers prioritize completing the prescribed curriculum while paying limited attention to developing students' thinking and comprehension skills (Almasaed, 2017; Gloria et al., 2017; Gotwals & Songer, 2009; Lynd Balta 2006; Khedivi & Malek-Mohammadi, 2008; Ozyurt et al., 2021; Saodah et al., 2023; Smith et al., 2008; Taheri et al., 2016). As a consequence, students frequently struggle with tasks requiring conceptual understanding and transfer rather than simple recall. Evidence from international assessments supports this concern. Data from large-scale assessments such as TIMSS show that students perform relatively well on items that require recall but experience substantial difficulty with tasks requiring reasoning, comprehension, and transfer of knowledge (Cho & Trent, 2005; Mullis & Martin, 2024).

These findings suggest that current instructional practices may not adequately support the development of deep understanding. Improving students' learning outcomes therefore requires reconsidering how curriculum and instruction are designed. Research suggests that effective curriculum design plays a crucial role in facilitating meaningful learning, retention, and transfer of knowledge (Bulgren et al., 2007; Gersten et al., 2006; Thehli & Mohamed, 2025). Without an appropriate curriculum, instruction cannot lead to understanding. Therefore, the curriculum must be carefully designed and able to address the unique learning needs of students. The reason many students fail to understand key concepts in the content is that instruction is often delivered through textbooks, lectures, worksheets, and activities that do not make learning meaningful for students (Scruggs et al., 2007; Surma et al., 2025). When instructional design aligns learning objectives, assessment methods, and teaching activities, it creates coherent learning environments that support deeper cognitive processing (Abazari et al., 2022).

One instructional framework that explicitly focuses on designing curriculum for meaningful understanding is Understanding by Design (UbD) (McTighe & Willis, 2019; Suryana et al., 2025; Wiggins & McTighe, 2006; Wiggins & McTighe, 2011). UbD emphasizes backward design, alignment of learning goals with assessments and instructional activities, and the promotion of knowledge transfer. Despite its strong

theoretical foundation and growing international recognition, this model has not been widely implemented in many educational systems, including elementary science education in our country. At the same time, research in cognitive psychology highlights the importance of considering learners' cognitive architecture when designing instruction. In particular, Cognitive Load Theory (CLT) emphasizes that effective instructional design should manage the limited capacity of working memory to facilitate learning (Clark et al., 2011; Paas & van Merriënboer, 2020; Skulmowski & Xu, 2022; Sweller, 2004). The results of studies by Zare et al. (2012), Zare (2014), Zare et al. (2014), as well as Tabbers et al. (2004), and Ouwehand et al. (2025) shown that designing instruction based on cognitive load principles is effective in improving academic performance. Therefore, instructional designers, by considering the components of cognitive load and effectively guiding learners to use working memory and reduce unnecessary mental effort, reduce additional cognitive load and optimize learning (Zhu, 2022)

Although UbD aims to foster meaningful understanding and transfer of learning, empirical evidence examining its impact on learners' cognitive processes, particularly cognitive load, remains limited. Given the importance of instructional design in shaping cognitive processing during learning, investigating the relationship between UbD and cognitive load may provide valuable insights for improving instructional effectiveness. Moreover, considering the unsatisfactory state of science education at the elementary level in our country, as reflected in the results of international assessments such as TIMSS, and the necessity of modifying or improving instructional methods and models, along with the emergence of the Understanding by Design (UbD) approach as a framework grounded in deep understanding, the importance of this issue becomes even more evident. On the one hand, the UbD approach has not been incorporated into teaching–learning activities in our educational system, and on the other hand, no research has been conducted on introducing, implementing, or examining its effects on various educational variables. Therefore, the main question of the present study is:

*What effect does the Understanding by Design (UbD) model have on students' cognitive load?*

## **T**heoretical Background and Literature Review

### **1. Understanding by Design (UbD)**

Understanding by Design (UbD) is a curriculum planning framework that focuses on designing instruction with the goal of promoting deep understanding and transfer of learning (Latifah et al., 2025; Wiggins & McTighe, 2011). According to Newell et al. (2023), the UbD framework provides a systematic process for aligning curriculum design, assessment practices, and instructional activities. The core elements of Understanding by Design (UbD) are: Backward Design, Big Ideas, Essential Questions, Enduring Understandings, Performance Tasks (or simply Performance), and Transfer. Central principle of UbD is backward design, which reverses the traditional sequence of curriculum planning. Instead of beginning with instructional activities, teachers first identify desired learning outcomes, then determine acceptable evidence of learning, and finally design instructional experiences that support those outcomes (Gürbüz & Yurtseven, 2026; Johnson et al., 2017; Kuntari et al., 2019; Yurtseven, 2016). Backward design consists of three main stages as illustrated in (Figure 1):

- Identifying desired results
- Determining acceptable evidence
- Planning learning experiences and instruction

In the first stage, learning outcomes are categorized into acquisition, meaning-making, and transfer (McTighe & Silver, 2020; Nguyen & Miller, 2025; Yurtseven, 2016). The second stage involves identifying evidence of learning, including performance tasks and other assessment strategies such as tests, observations, and portfolios (Wiggins & McTighe, 2011). Performance tasks often involve authentic contexts that require students to apply knowledge to real-world problems. These elements help ensure that learning activities are authentic and aligned with intended outcomes. In the final stage, teachers design

learning experiences that guide students toward achieving the desired outcomes (Afidah & Hernawan, 2025; Wiggins & McTighe, 2007).

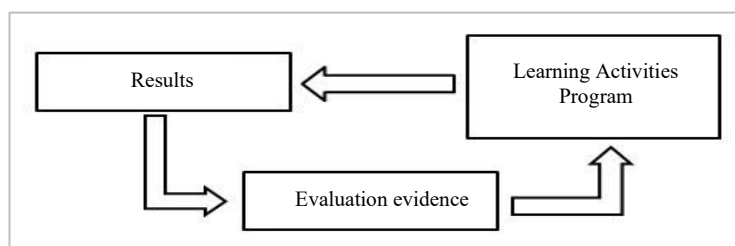


Figure 1: Backward design Steps (Heizel & Salayo, 2010).

It is noteworthy that, to assist teachers in designing meaningful performance tasks, the UbD model introduces the *GRASPS* framework, which includes Goal, Role, Audience, Situation, Performance, and Standards for success (McTighe & Silver, 2020; McTighe & Willis, 2019; Wiggins & McTighe, 2006, 2011). These elements help ensure that learning activities are authentic, purposeful, and aligned with intended learning outcomes, thereby supporting deeper understanding and meaningful transfer of knowledge (McTighe & Silver, 2020; McTighe & Willis, 2019).

According to Afidah and Hernawan (2025), and Wiggins and McTighe (2011) propose the *WHERE TO* framework to support effective instructional planning. This framework includes elements such as clarifying learning goals (Where & Why), engaging learners (Hook), equipping students with necessary knowledge (Explore & Equip), encouraging reflection (Rethink & Reflect), and tailoring instruction to learner needs. Central to the UbD framework is the concept of understanding, which is described as a multidimensional construct encompassing six facets: explanation, interpretation, application, perspective, empathy, and self-knowledge (Yurtseven, 2016). These facets emphasize that understanding goes beyond factual recall and involves flexible and meaningful use of knowledge. Big ideas are the foundation of understanding because they help integrate scattered pieces of information and bring them together into a coherent whole (Snook, 2019). Essential questions are questions that stimulate authentic inquiry related to the big ideas of the core content; they promote deep thinking, lively discussion, new understanding, and the generation of further questions (Afidah & Hernawan, 2025; Ramli & Argaswari, 2023).

Another key concept in UbD is transfer, defined as the ability to apply knowledge and skills effectively in new situations (Ramli & Argaswari, 2023). Transfer represents the ultimate goal of meaningful learning and serves as an important criterion for evaluating whether students have achieved intended learning outcomes (McTighe & Silver, 2020; Wiggins & McTighe, 2011). Standards have been defined to ensure the quality of design in the “Understanding by Design” (UbD) model. These standards function as guidance for teachers, enabling them to use them when evaluating themselves and their peers (Nayman et al., 2020; Nguyen & Miller, 2025).

A schematic diagram of the steps for implementing “UbD” is shown in (Figure 2).

## 2. Cognitive Load Theory (CLT)

Cognitive Load Theory (CLT) provides a theoretical framework for understanding how the structure of instructional materials influences learning processes. The theory is grounded in assumptions about human cognitive architecture, particularly the limited capacity of working memory and the virtually unlimited capacity of long-term memory (Orhani & Canhasi-Kasemi, 2026; Sweller, 2004; Van Merriënboer & Ayres, 2005). Cognitive load refers to the mental effort imposed on working memory during learning activities (Eesee et al., 2025; Velayati et al., 2018). According to CLT, effective instructional design should manage three types of cognitive load: intrinsic load, extraneous load, and germane load. The main claim of this theory is that the effectiveness of instructional design without knowledge and information about the human cognitive structure is likely to be random. Cognitive Load Theory argues that many traditional teaching methods have not properly considered the limitations of the human cognitive structure, as they

unnecessarily overload the learner’s working memory, the central core of the cognitive system. Accordingly, Cognitive Load Theory seeks to integrate knowledge about the structure and functioning of the human cognitive system with the principles of instructional design (Esee et al., 2025; Schnotz et al., 2009).

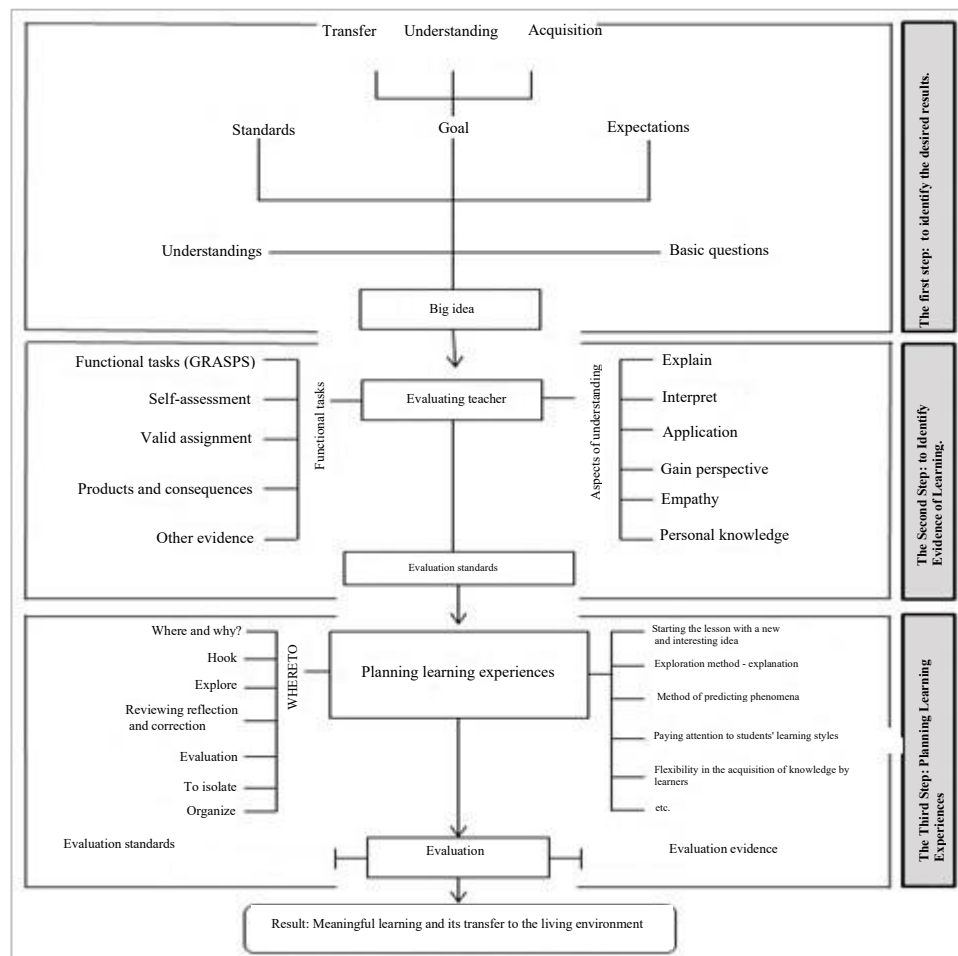


Figure 2: Schematic of the steps for implementing “Understanding by Design”.

Research has shown that instructional strategies designed in accordance with cognitive load principles can significantly improve learning efficiency and performance (Kalyuga et al., 2001). By reducing unnecessary processing demands, instructional design can enable learners to allocate cognitive resources more effectively to meaningful learning processes. Recent studies further emphasize the importance of structured instructional design in managing cognitive load. Aligning learning goals, tasks, and assessments reduces extraneous cognitive load and enhances instructional efficiency. Other recent research has also demonstrated that instructional clarity and structural coherence can reduce cognitive stress and improve learners’ engagement and self-regulation. Furthermore, Lan et al. (2025) found that instructional models that integrate clear learning objectives with aligned assessment and instructional activities significantly improve self-regulated learning while reducing perceived cognitive load. Emerging evidence also suggests that reducing unnecessary processing demands in working memory supports deeper conceptual learning and knowledge integration (Zheng et al., 2026).

### 3. Relationship between Instructional Design and Cognitive Load

Recent research increasingly highlights the role of instructional design models in managing learners’ cognitive load. Instructional approaches that emphasize structured learning environments, meaningful tasks, and alignment between instructional elements appear particularly effective in reducing extraneous cognitive

load and supporting conceptual understanding. For example, Willingham (2009) demonstrated that when students apply knowledge in authentic contexts, their ability to retain and retrieve information improves significantly. Similarly, Chang et al. (2022), Lan et al. (2025), and Zheng et al. (2026) reported a significant relationship between practical learning activities and cognitive load in experimental learning environments.

Given that the UbD framework emphasizes authentic performance tasks, meaningful understanding, and transfer of learning, it may provide conditions that optimize cognitive processing during learning. However, empirical research examining the relationship between UbD and cognitive load remains limited, particularly in elementary science education. Therefore, investigating the impact of UbD-based instruction on students' cognitive load can contribute to both instructional design research and the improvement of science education practices.

## Research Method

The aim of the present study was to investigate the effect of a curriculum based on the Understanding by Design (UbD) approach on sixth-grade students' cognitive load in elementary science education. In terms of purpose, the study was applied in nature, as its findings are intended for use in the teaching–learning process. With respect to data collection, the study employed a quasi-experimental design with two groups (experimental and control) using a pre-test–post-test structure. The statistical population consisted of all sixth-grade elementary school students in Shabestar City during the 2022–2023 academic year. Based on the quasi-experimental design and Cohen's sample size table (power = 0.80, two groups, effect size = 0.50, significance level = 0.05), a sample of 60 students was selected. Participants were drawn from sixth-grade male students using a multistage random sampling method, made possible by the availability of the sampling frame, and were then randomly assigned to either the experimental group ( $n = 30$ ) or the control group ( $n = 30$ ). The experimental group received instruction based on a UbD-based curriculum designed by the researcher according to the principles of the UbD model for the sixth-grade science course. The content validity of this curriculum was confirmed by five curriculum planning experts and five experienced elementary school teachers. The control group received conventional classroom instruction. To control for potential confounding variables, the two groups were homogenized in terms of baseline characteristics, subject matter, and teacher. Additionally, the administration of a pre-test in both groups helped control for initial differences and moderated the effect of the independent variable on the dependent variable. Following the pre-test, the instructional intervention was implemented over four weeks in eight sessions. One week after the completion of the instructional sessions, the cognitive load post-test was administered to both the experimental and control groups. For data analysis stemming from the implementation of the Understanding by Design-based curriculum model and for comparing the control and experimental groups, univariate analysis of covariance (ANCOVA) was employed. In this study, students' cognitive load was measured using the Cognitive Load Rating Scale developed by Paas (1994). The instrument consists of four items rated on a 9-point Likert scale, ranging from very easy (1) to very difficult (9). Each item assesses the perceived mental effort during learning (e.g., How difficult was it for you to understand and comprehend the presented material?). It measures cognitive load, and a lower score on this questionnaire indicates a lower level of cognitive load.

Regarding validity, the original version of the scale has been widely used and validated in numerous studies across instructional and cognitive psychology contexts (Paas et al., 1994). Its content validity was confirmed by expert review in the present research, involving five curriculum planning experts and five experienced elementary school teachers, who verified the appropriateness of the items for sixth-grade science instruction. Concerning reliability, Paas et al. (1994) reported an internal consistency (Cronbach's  $\alpha$ ) of 90%, and a reliability of 82% in their studies. In a local adaptation by Salari and Amirteimouri (2017), the Cronbach's  $\alpha$  was 85%, confirming acceptable reliability in the Iranian context. In the present study, the reliability coefficient of the instrument was recalculated and found to be  $\alpha = 84\%$ , indicating high internal consistency and suitability for the current sample. Therefore, both the validity and reliability

evidence indicate that the adapted version of the Paas (1994) Cognitive Load Scale is appropriate for measuring cognitive load among sixth-grade students in the Iranian elementary school context.

## Research findings

In this section, descriptive statistics—including frequency distributions, minimum and maximum values, means, and standard deviations—are first presented to characterize the research variable across the study groups. Subsequently, the research hypothesis is tested using inferential statistics, specifically a univariate analysis of covariance (ANCOVA), performed with SPSS version 25.

**Table 1:** Descriptive statistics of the research variable.

Standard deviation	Average	Maximum	Minimum	Number	Group	Test	Research variables
0.44	4.39	5.25	3.50	30	Control	Pre-test	Cognitive load
0.73	4.30	5.25	2.75	30	Test		
0.32	4	4.50	3.50	30	Control	Post-test	
0.25	1.56	2	1	30	Test		

Descriptive statistics for the cognitive load variable are presented in Table 1, including the minimum, maximum, mean, and standard deviation values. Inferential statistical analysis of the research hypothesis data:

### a) Assessment of Normality

The Kolmogorov–Smirnov test was used to assess the normality of the data, and the results are presented in Table 2. The test was conducted at a 95% confidence level with a significance threshold of  $\alpha=0.05$ . A  $p$ -value greater than  $\alpha=0.05$  indicates that the data distribution does not significantly deviate from normality.

**Table 2:** Results of the Kolmogorov–Smirnov test for Normality of Pre-test and Post-test Scores by Group (Control and Experimental).

POST-TEST		PRE-TEST		NUMBER	GROUP	Variable
Significance level	Test statistic	Significance level	Test statistic			
0.200	0.170	0.200	0.102	30	Test	Test
0.120	0.198	0.166	0.187	30	Control	

Based on the pre-test–post-test control group design, a one-way analysis of covariance (ANCOVA) was conducted to control for and neutralize the effect of the pre-test on the dependent variable across both groups. In the present study, the independent variable was the type of instruction, operationalized as the implementation of the UbD-based curriculum in the experimental group versus conventional instruction in the control group. The dependent variable was students’ cognitive load measured at the post-test stage. In addition, pre-test cognitive load scores were entered into the analysis as a covariate in order to control for initial differences between the two groups.

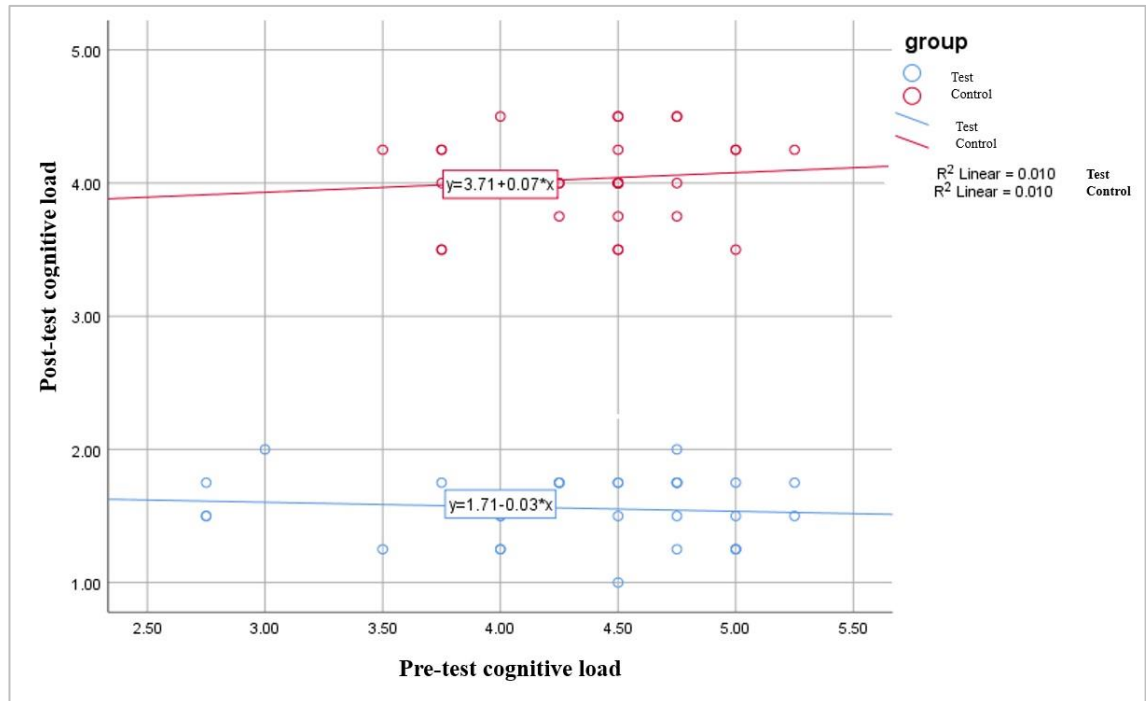
### Hypothesis Testing:

*Is there a significant difference in cognitive load between students in the experimental group and those in the control group?*

### Assumptions:

#### 1) Linearity

The assumption of linearity was examined by assessing the linear relationship between pre-test cognitive load scores (covariate) and post-test cognitive load scores (dependent variable).



**Figure 3:** Distribution of students' cognitive load in pre-test and post-test according to experimental and control groups

According to the graph, the slopes of the regression lines are non-zero, indicating the presence of a linear relationship between pre-test scores and the dependent variable (post-test cognitive load following the implementation of the Understanding by Design curriculum). Moreover, the regression lines appear to be parallel, suggesting homogeneity of regression slopes and the absence of an interaction effect between the covariate (pre-test scores) and the group variable. This condition satisfies one of the key assumptions of analysis of covariance (ANCOVA), which is further examined in the subsequent statistical test. In addition, the coefficient of determination reflects the strength of the relationship between the covariate and the dependent variable.

### b) Examination of the Homogeneity of Regression Slopes:

**Table 3:** Effects of between-group test to check the homogeneity of regression slopes.

Significance level	<i>F</i>	Mean squares	Degree of freedom	Sum of squares	Source of changes
0.003	9.993	0.870	1	0.870	<b>Group</b>
0.784	0.076	0.007	1	0.007	<b>Cognitive load Pre-test</b>
0.0458	0.560	0.049	1	0.049	<b>Group* Cognitive loa Pre-test</b>
		0.087	56	4.878	<b>Error rate</b>
			60	565.813	<b>Total</b>

Given that the interaction effect between group membership and pre-test cognitive load was not statistically significant ( $p = 0.458 > 0.05$ ), there was no significant interaction between the experimental condition and the covariate. This result confirms that the assumption of homogeneity of regression slopes was met; therefore, the use of a one-way ANCOVA is appropriate.

**c) Examination of Homogeneity of Variances:**

**Table 4:** Results of Levene's Test to check the assumption of homogeneity of variances.

Significance level	Degree of freedom	Degree of freedom	(F) Amount	Dependent variable
0.302	58	1	1.084	Post-test academic progress

The results presented in Table 4 indicate that the assumption of homogeneity of variances between the experimental and control groups was met ( $p \geq 0.05$ ). In other words, because the significance level exceeded 0.05, the variances of the two groups on the dependent variable can be considered equal. Given that all assumptions, linearity, homogeneity of regression slopes, and homogeneity of variances, were satisfied, a one-way analysis of covariance (ANCOVA) was conducted to test the research hypothesis.

**Table 5:** Results of the covariance test of the difference between the control and experimental groups in the cognitive load variable.

Eta squared	Significance level	(F)Amount	Mean squares	Degree of freedom	Sum of squares	Source of changes
0.643	0.931	0.008	0.001	1	0.001	Cognitive load – Pre test
0.949	0.0001	1058.403	91.476	1	91.476	Group
			0.086	87	4.926	Error rate
				60	565.813	Total

Based on the findings presented in Table 5, a significant difference was found in post-test cognitive load between the experimental and control groups following the implementation of the UbD curriculum,  $F(1, 57) = 1058.403, p = 0.00, \eta^2 = 0.949$ . Considering that ANCOVA controls for the effect of pre-test scores and provides adjusted means, the adjusted means for the groups are as follows:

**Table 6:** Adjusted mean of post-test academic achievement score by group (experiment and control).

95% confidence interval		Standard error	Average	Group	Variable
Upper limit	Lower limit				
1.666	1.450	0.054	1.558	Test	Cognitive load Post-test
4.141	3.926	0.054	4.034	Control	

Based on Table 6, the adjusted mean scores of cognitive loads after the implementation of the Understanding by Design curriculum model were lower in the experimental group (1.558) than the cognitive load scores in the control group (4.034). In other words, the Understanding by Design-based curriculum model had an effect on reducing cognitive load in students. Considering the eta squared value, it can be stated that 94.9% of these changes were due to the effect of the experiment or the implementation of the Understanding by Design-based curriculum model.

As explained, the post-test of cognitive load was administered using a simplified and translated version of the Paas (1994) scale, which had been approved in a pilot phase and by subject-matter experts and experienced elementary teachers. The researcher's observations during the post-test indicated that students understood and completed the items without difficulty, and the instrument demonstrated adequate internal consistency ( $\alpha = 0.84$ ). These findings indicate that the testing method was appropriate for sixth-grade students. During the UbD instruction, due to the nature of the subject and grade level, practical activities such as experiments, graph drawing, and performance-based projects were employed; only the post-test measurement instrument was administered in written form.

Accordingly, in the present study, the independent variable was the UbD-based curriculum implemented in the experimental group, and the dependent variable was students' cognitive load, which was measured after the instructional intervention. The pre-test cognitive load scores were included as a covariate in the

ANCOVA analysis to control for initial differences between the groups. In addition, several contextual variables, such as the subject matter (science), grade level (sixth grade), and teacher, were controlled to ensure comparability between the experimental and control groups. The results of the ANCOVA analysis showed that the UbD-based curriculum had a statistically significant effect on students' cognitive load, with a very large effect size ( $\eta^2 = 0.949$ ). This indicates that a substantial proportion of the variance in cognitive load was explained by the instructional intervention.

The results of the assumption checks indicated that the data were suitable for conducting a one-way ANCOVA. The Kolmogorov–Smirnov test showed that the cognitive load scores in both groups were normally distributed ( $p > .05$ ). The scatterplots also demonstrated a clear linear relationship between the pre-test scores (covariate) and the post-test cognitive load scores. The test for homogeneity of regression slopes was not significant ( $p = .458$ ), indicating that the slopes were similar in both groups. Overall, all assumptions of ANCOVA were met; therefore, the analysis could be properly conducted using ANCOVA.

## Discussion

The present study investigated the impact of the Understanding by Design (UbD) curriculum framework on sixth-grade students' cognitive load in elementary science. The results showed that students in the UbD group obtained substantially lower adjusted mean cognitive load scores (1.558) compared with their peers in the control group (4.034), indicating that UbD-based instruction significantly reduced learners perceived cognitive load. Moreover, the analysis of covariance (ANCOVA) showed a statistically significant difference between the experimental and control groups. In addition to the significance test, the effect size was also examined. The obtained eta squared value ( $\eta^2 = 0.949$ ) represents a very large effect size. This indicates that the magnitude of the intervention's impact was highly substantial, not merely a simple statistically significant difference, but an exceptionally strong and meaningful effect. In other words, the Understanding by Design (UbD) curriculum model had a significant effect on reducing students' cognitive load. Considering the eta squared value, it can be stated that 94.9% of these changes were due to the impact of the experimental intervention, that is, the implementation of the UbD-based curriculum model.

Beyond demonstrating statistical significance, these findings can be fruitfully interpreted in the light of contemporary developments in Cognitive Load Theory (CLT) and curriculum design research. According to CLT, learning is constrained by the limited capacity of working memory, and instructional design must optimally manage intrinsic, extraneous, and germane cognitive load. Poorly structured instruction often increases extraneous load by imposing unnecessary processing demands that are not directly related to the learning goals. UbD's backward design process, starting with clearly specified learning outcomes, then identifying acceptable evidence, and finally planning aligned learning experiences (Nguyen & Miller, 2025; Wiggins & McTighe, 2006), appears to function as a macro-level load management mechanism. By eliminating misaligned tasks and redundant content, UbD likely reduces extraneous load and allows a greater proportion of working-memory resources to be devoted to germane processing and schema construction (Ouwehand et al., 2025; Paas & Van Merriënboer, 2020).

This interpretation is consistent with recent research highlighting that structural alignment of objectives, assessments, and instructional activities enhances cognitive efficiency and reduces perceived mental effort (Lan et al., 2025; Zheng et al., 2026). Studies on instructional coherence suggest that when learners clearly understand what they are expected to learn and how their learning will be assessed, they are better able to allocate attention and regulate their cognitive resources. In our study, the lower cognitive load in the UbD group can be interpreted as a consequence of goal transparency and curricular coherence, both of which are central features of UbD. From the perspective of schema theory, meaningful learning involves the construction and automation of cognitive schemas that enable learners to integrate and retrieve information efficiently (Suryana et al., 2025; Van Gerven et al., 2002). UbD's emphasis on understanding and transfer, particularly through real-life performance tasks, provides rich opportunities for students to build and refine schemas that can be applied across contexts. This focus on transfer may explain why our findings converge

with prior research showing that connecting classroom learning to authentic situations facilitates long-term retention and retrieval (Chang et al., 2022; Gürbüz & Yurtseven, 2026; Suryana et al., 2025; Willingham, 2009). As schemas become more automated, working-memory demands during complex tasks are reduced, which aligns with the lower cognitive load reported by students in the UbD condition.

## Conclusion

The present findings contribute to the growing body of evidence suggesting that curriculum-level interventions may be more powerful in managing cognitive load than isolated strategy-level interventions. Recent conceptual and empirical work (Lan et al., 2025; Paas & Van Merriënboer, 2020) argue that CLT principles should be embedded not only in micro-level lesson design but also in macro-level curriculum planning. Our study supports this claim by showing that a curriculum framework like UbD, explicitly organized around desired results and backward planning, can translate CLT principles into systemic instructional practice. In this sense, UbD can be viewed as an instantiation of CLT at the curriculum level, where the alignment of goals, evidence, and learning experiences acts as a structural safeguard against cognitive overload. The educational implications of these findings are particularly relevant in systems where elementary science curricula are dense and time-pressured. By reducing unnecessary mental effort and focusing students' attention on core conceptual understandings, UbD may enhance both the efficiency and quality of learning. This resonates with prior CLT-based interventions showing that instruction designed to minimize extraneous load and optimize germane load leads to improved academic performance and deeper understanding (Abdi & Rostami, 2017; Ouwehand et al., 2025; Rezazadeh-Sharmeh & Hashemi, 2010; Shiralinejad et al., 2012).

In summary, this study provides contemporary empirical support for the integration of UbD and Cognitive Load Theory. The findings suggest that aligning learning objectives, assessment evidence, and instructional activities within a backward design framework is not merely a pedagogical preference but a cognitive necessity for managing students' mental effort and promoting meaningful scientific understanding. For educational policymakers and curriculum planners, these results underscore the value of adopting UbD-informed curricula and investing in teacher professional development programs that explicitly connect curriculum design with principles of cognitive architecture.

## Limitations and Suggestions for Future Research

Several limitations should be acknowledged. First, the study was limited to sixth-grade students in one region, which constrains the generalizability of the findings. Second, implementation fidelity of UbD and teachers' prior familiarity with the framework were not experimentally manipulated; thus, variation in teachers' UbD competence may have influenced the magnitude of the observed effects. Third, cognitive load was assessed via self-report (the PASS Cognitive Load Questionnaire), which, although widely used, captures perceived rather than objective load. Future research could address these limitations by (a) including multiple grade levels and subject areas, (b) employing longitudinal designs to examine whether reduced cognitive load translates into durable conceptual understanding and transfer, and integrating objective indicators of cognitive load such as dual-task performance, physiological measures, or eye-tracking.

### Finding

An example of a design based on the Understanding by Design Model for the Nutrition Lesson in the Sixth Grade Experimental Science Textbook:

Designing a Learning Unit with an Understanding by Design (UbD)	
Title: Nutrition and Metabolism Topic: Nutrition and Health	Course: Experimental Sciences Designer:

## Step 1: Desired results

### Defined goals:

Students will be able to independently use their learning to:

- Identify healthy eating habits necessary for maintaining a proper diet.
- Maintain a balanced (rational) diet.
- Recognize the consequences of an unbalanced diet.

### Basic Questions/Big Idea :

- How can different types of food be classified?
- What role does each type of food play in the body?
- How should the qualitative and quantitative needs of the body be met in different situations?
- What does a balanced diet consist of?
- What are the health risks of an unbalanced diet?

### Understanding :

#### Students understand that :

- Food is the source of energy for cells and provides nutrients for the body .
- Food must meet the body's energy needs on the one hand and the body's need for nutrients on the other.
- Balancing calorie (food) intake and expenditure is essential for maintaining health.

### Students will be able to:

- Classify different types of foods in a table according to their chemical composition, role, and function.
- Calculate the amount of energy provided to the body by organic substances in each meal.
- Compare the body's nutritional needs in different situations.
- Interpret variations in the need for certain nutrients across different physiological states.
- Analyze the charts presented in these chapters.
- Determine the components of a balanced diet.
- Prepare a list of various nutritional diseases, including their symptoms and causes.
- Differentiate nutritional diseases based on their symptoms.
- Calculate body mass index (BMI) and determine whether obesity is present.

### Students will know that:

- Foods can be classified into six groups according to their chemical composition: proteins, lipids, carbohydrates, vitamins, mineral salts, and water.
- Foods can also be classified into three groups based on their function in the body: the regulatory group (vitamins and minerals), the energy-providing group (carbohydrates and fats), and the structural or body-building group (proteins).
- The oxidation of organic food substances (proteins, lipids, and carbohydrates) releases energy, which is expressed in kilojoules.
- A dietary ration (food ration) refers to the quantity and types of food consumed by an individual over a given period, usually one day.
- Dietary requirements vary according to several factors, including age, sex, physiological state, level of physical activity, and climate.
- A balanced diet consists of a variety of foods consumed in appropriate proportions.
- Inadequate nutritional intake leads to an unbalanced diet.
- An unbalanced diet can cause serious nutritional diseases.
- Examples of nutritional disorders include vitamin deficiency diseases such as rickets and conditions caused by overeating, such as obesity.
- Dietary patterns vary according to economic, social, and cultural factors.

## Step 2 - Evaluation Evidence

### Functional task:

Objective (Scenario): Students are asked to examine a meal consisting of: potatoes, cheese, bread, grilled meat, butter in terms of: determining the amount of energy produced for this meal and whether the energy produced from this meal is more than needed or not? and also whether this meal is balanced or not?

### Role:

Students are asked to divide into several groups, each group having, in addition to the chart on page 102, a suitable meal and a digital scale to weigh the food to calculate the energy content for this meal.

### Attendees' activities:

Teams share information and conclusions with each other and with the other team.

### Group composition:

Depending on the number of students in the class, each team consists of four students (approximately 6 teams per class).

### Execution:

Each team uses a digital scale and a 102 chart to show the energy values of a meal consisting of potatoes, meat, bread, butter, and cheese. Each team weighs the food in a different way than the others according to the table below:

Amount of cheese (grams)	Amount of potatoes (grams)	Amount of meat (grams)	Amount of butter (grams)	Bread quantity (grams)	Group number
50	20	100	20	130	1
50	20	100	100	130	2
50	20	100	20	200	3
50	100	100	20	130	4
50	20	200	20	130	5
100	100	100	20	130	6

After weighing the quantities, each team begins to determine the amount of energy generated from each type of food using a chart, then calculates the amount of energy provided by this meal and compares it to the daily energy requirement (1800 kcal).

Each team then draws conclusions about whether the meal is balanced or not and understands which types of food should be reduced or increased to maintain a reasonable diet. At the end, each team shares its results.

### Standards:

Remind students working in their teams of important points.

Students should understand the topic before starting the activity.

**Other evidence:**

Homework to solve supplementary exercises;  
Research on nutritional diseases other than those mentioned in this chapter, focusing on their causes and symptoms;  
Participate in this season's exam;

**Step 3 - Learning Plan****Activity 1: Food Variety**

We read the introduction, then ask students to name some foods. We also write their names on the page, and then ask them to classify these foods into different categories based on random criteria in their opinion.  
We keep the answer on the page and then go back to the book and start observing/analyzing the figures and numbers in the text. After that, students revise their classification.

We ask students: Where do we get our energy? How is food converted into energy?

We brainstorm and then explain the concept of oxidation (the process of combining oxygen with another substance).

Finally, we perform the energy calculation by solving an exercise and ask students to work in their groups to solve the textbook class activity.

**Activity 2: Diet**

I first brainstorm with the students by asking them the following questions:

How many meals do you eat a day?

What do their meals consist of?

What type of food do they prefer?

Then I explain the concept of a diet. Then I describe a man to them in three situations: a man walking, a man sitting at his desk, a man running.

And I ask them: Do these three men need the same diet? Which one needs more food? Why?

Students will learn here that diet varies based on many factors. I ask them to analyze worksheet/assignment number (four) and then share the results.

**Activity 3: Balanced diet**

We read the introduction, then ask students to turn to page 99 (concept map) to identify the difference between a balanced and unbalanced diet and to infer the state of a rational diet.

Then, using films and some images (via projector), we focus on diseases that originate from malnutrition.

Students prepare a table for the 4 main nutritional diseases: for example: kwashiorkor, marasmus, rickets and obesity, and then list their causes and symptoms.

After completing this chapter, they will now be able to solve the exercises on pages 101 to 103.

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