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An Investigation of the Impact of Science Lessons Based on UbD Practices on Middle School Students' Achievement and 21st Century Skills*

Yasemin Çim [1*], Sertel Altun [2]

Abstract

The aim of this study is to examine the impact of implementing the "Human and Environment" unit in the 5th-grade Science curriculum revised in 2018 according to the Understanding by Design (UbD) approach on students' academic achievement and 21st-century skill levels. A needs analysis was first conducted at a public middle school in Istanbul, Türkiye. Based on the findings of this analysis, a 20-hour UbD-based instructional plan was developed and implemented with the experimental group. The study was limited to the "Human and Environment" unit of the 5th-grade Science course during the second semester of the 2023–2024 academic year, and UbD practices were applied only within this unit. The duration of the research was five weeks, corresponding to the instructional period of the selected unit. The teaching process was implemented as planned throughout the experimental phase. A quantitative research method was adopted, utilizing a pretest–posttest control group experimental design. Achievement and skills tests were administered to both the experimental and control groups before and after the intervention. A total of 58 students participated in the study, with 29 students in each group. The quantitative data obtained were analyzed using dependent and independent samples t-tests, based on the assumption of normal distribution. The results revealed statistically significant differences in favor of the experimental group between pretest and posttest scores, as well as between the posttest scores of the experimental and control groups. These findings demonstrate that the UbD approach is effective in enhancing students' academic achievement and skill levels.

Keywords: Achievement, Instructional Design, Understanding by Design (UbD).

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[1] **Yasemin Çim,** Yıldız Technical University, İstanbul, Türkiye. ORCID: 0009-0009-4543-8333, yasemin.cim@std.yildiz.ed.tr
* **Correspondence:** yasemin.cim@std.yildiz.ed.tr

[2] **Sertel Altun,** Yıldız Teknik Üniversitesi, Türkiye. ORCID: 0000-0002-1951-5181, saltin@yildiz.edu.tr

INTRODUCTION

Since the dawn of existence, humans have been driven by a deep sense of curiosity about nature, life, and themselves. This innate curiosity begins in early childhood within the family environment and continues in a more structured manner within the school setting. In this context, schools assume a significant societal role as fundamental institutions responsible for equipping individuals with knowledge, skills, and values. Rapid social, scientific, and technological transformations, along with shifting expectations in the labor market, have led to a redefinition of individual competencies—consequently altering the roles expected of schools (MoNE, 2023).

Twenty-first-century education necessitates not only the transmission of knowledge but also the cultivation of multifaceted competencies such as critical thinking, collaboration, creativity, and lifelong learning (Partnership for 21st Century Learning, 2019). Within this scope, it is essential to structure curricula and design instructional practices in ways that promote these skills. The Understanding by Design (UbD) approach, which aims to provide students with meaningful and enduring learning experiences, has emerged as an effective instructional model in this regard (Wiggins & McTighe, 2005).

The theoretical foundations of science education are rooted in constructivist learning theory. This approach, which emphasizes active student participation and learning through experience, asserts that knowledge is constructed by the individual and that learning is inherently a social process. Therefore, process-oriented practices such as experimentation, observation, discussion, and collaboration are essential components of science instruction (Driver et al., 1994). Equipping students with these competencies is not only a personal necessity but also a strategic imperative for national development. In alignment with this perspective, Turkey's 2018 revised curriculum placed a strong emphasis on 21st-century skills, particularly within the Science course, by integrating relevant learning outcomes and instructional practices (MoNE, 2018).

In today’s evolving global landscape, the competencies expected of individuals are grouped under the umbrella of 21st-century skills. Abilities such as analytical thinking, creativity, communication, problem-solving, and teamwork have become key determinants of both academic success and overall quality of life (Trilling & Fadel, 2009).

In the international context, Turkey’s science education policies are shaped by the influence of organizations such as the OECD, UNESCO, and PISA. In particular, PISA and TIMSS assessments hold significant value for benchmarking students’ scientific literacy levels through international comparisons. Monitoring reports published by the Ministry of National Education (MoNE) have underscored the need to restructure both curricula and teacher training in light of these data (MoNE, 2023).

Rather than focusing solely on the transmission of knowledge, modern curricula prioritize meaningful and lasting learning. This approach emphasizes students' active engagement with content through experience, inquiry, and the connection of new knowledge to prior understanding (Wiggins & McTighe, 2005). The Understanding by Design (UbD) model offers a robust framework for applying this philosophy to instructional planning. McTighe and Wiggins (1999) argue that mere knowledge acquisition is insufficient; true understanding involves the ability to transfer, interpret, and critically evaluate information across contexts. In this regard, UbD can be described as a student-centered instructional model that places individual differences at its core (Altun & Yurtseven, 2021).

The Science course plays a fundamental role in enhancing scientific literacy, supporting inquiry-based thinking, and promoting knowledge acquisition that is relevant to real-life contexts. According to the 2022 PISA report, Turkey scored below the OECD average in science literacy, and only 4% of students demonstrated performance at the highest proficiency levels (MoNE, 2024). This statistic underscores the need to reassess existing instructional models, particularly in terms of their ability to foster high-order skills such as critical thinking and problem-solving.

Although the TIMSS 2023 data indicate that eighth-grade students in Turkey have improved their international rankings, the results also highlight significant areas for development, particularly in variables such as subject comprehensibility, student attitudes, and self-efficacy. For instance, 29% of students reported a lack of confidence in science, and 24% expressed that they did not value the subject (MoNE, 2024).

These findings suggest that current curricula fall short in equipping students with the skills required by the modern age and point to the need for more effective instructional approaches. At this juncture, the Understanding by Design (UbD) model emerges as a promising framework. It facilitates meaningful learning experiences, encourages students to recognize interdisciplinary connections, and supports the transfer of knowledge across varied contexts (Altun & Yücel Toy, 2020).

In 2023, Turkey's Ministry of National Education published a comprehensive research report that systematically defined 21st-century competencies within a national framework. The report identified seven core skill domains—higher-order thinking, language and communication, learning, self, socio-emotional, work-related, and literacy—as well as eleven foundational values such as justice, honesty, and responsibility. It further recommended the integration of these competencies and values into existing curriculum structures (TTKB, 2023).

The 2018 revision of the Science curriculum redefined the roles of both students and teachers. In this updated framework, students are positioned as active learners who construct knowledge, question concepts, relate new information to prior knowledge, and transfer learning to novel situations. Teachers, meanwhile, are expected to serve as facilitators, guides, and organizers of the learning environment (MoNE TTKB, 2018). In order to operationalize these roles effectively, instructional design must be restructured around students' experiences. Ultimately, the current limitations of Turkey's curricula in equipping students with 21st-century skills underscore the growing importance of constructivist and meaning-centered instructional designs in preparing youth for the future.

The integration of science education with 21st-century skills necessitates the redesign of instructional practices accordingly. Approaches such as Inquiry-Based Learning, STEM (Science, Technology, Engineering, and Mathematics), experiential learning, and project-based learning provide direct opportunities for the development of these competencies (Saavedra & Opfer, 2012). These pedagogical strategies contribute to nurturing students not merely as consumers of information but as individuals who generate knowledge and apply it meaningfully across diverse contexts. The Understanding by Design (UbD) model stands out as a student-centered and transformation-oriented framework that effectively addresses this need. Several studies conducted in Turkey have demonstrated that UbD significantly enhances students' acquisition of 21st-century skills. For instance, Özdemir (2021) and Gürbüz (2022) found that science courses structured around the UbD model led to significant improvements in students' collaboration, problem-solving, communication, and creative thinking abilities.

Numerous studies conducted at the middle school, high school, and university levels have shown that the UbD framework supports students' cognitive and affective development. For example, experimental research integrating UbD with the flipped classroom model in science and chemistry courses demonstrated that students in the experimental groups achieved significantly higher scores on academic achievement tests compared to those in control groups, and their learning outcomes were found to be more enduring (Çinkaya, 2022). Similarly, UbD programs implemented in early childhood education have been reported to enhance children's receptive language development and improve teachers' instructional planning competencies (Yurtseven & Doğan, 2018).

In the context of English language instruction, the UbD approach has proven effective in improving students' speaking skills and enhancing teachers' pedagogical design knowledge and competencies (Yurtseven & Altun, 2017). Applications of UbD in mathematics and science have helped students overcome conceptual misconceptions and foster cognitive flexibility (Ayyıldız, 2023).

Likewise, implementations in social studies and sustainability education have led to significant improvements in collaboration, problem-solving, and student awareness (Erdağı, 2024; Uçar, 2024).

Graduate-level research in Turkey conducted by scholars such as Akbaş (2018), Açar (2020), Uyguç (2021), and Gürbüz (2022) has examined the implementation processes of the UbD model across various disciplines in relation to student achievement, motivation, and teacher perspectives. These studies reveal that integrating UbD into instructional programs enhances the systematicity and coherence of teachers' planning processes, while also enabling students to achieve more meaningful learning outcomes.

In light of these objectives, the present study aims to examine the effects of UbD-based instructional practices in the Science course on middle school students' academic achievement and their levels of 21st-century skills. This section of the study seeks to answer the following research questions:

Main Research Question:

What is the effect of Understanding by Design-based instructional practices on students' academic achievement and 21st-century skill levels in science courses?

Sub-Questions:

1. Is there a significant difference between the pre-test and post-test total scores of the experimental group in the achievement test?

2. Is there a significant difference between the pre-test and post-test total scores of the control group in the achievement test?

3. Is there a significant difference between the post-test total scores of the experimental and control groups in the achievement test?

4. Is there a significant difference between the pre-test and post-test total scores of the experimental group in the skills test?

5. Is there a significant difference between the pre-test and post-test total scores of the control group in the skills test?

6. Is there a significant difference between the post-test total scores of the experimental and control groups in the skills test?

METHODOLOGY

In this study, a quantitative research method was employed. The research design utilized a pretest–posttest control group experimental design, which allows for the comparative examination of the effect of a specific independent variable (intervention) on a dependent variable. Within the scope of the study, instructional activities based on the Understanding by Design (UbD) approach were implemented in the experimental group, while the control group continued instruction in line with the existing curriculum. Achievement tests were administered to both groups before and after the intervention, and the differences in students' academic performance were statistically analyzed.

Research Group

The research group consisted of 58 fifth-grade students enrolled in a public middle school located in Istanbul, Türkiye. The experimental and control groups were randomly selected from among the fifth-grade classes taught by the instructor. The experimental group included 29 students—17 girls and 12 boys—while the control group also comprised 29 students—14 girls and 15 boys. The students were between the ages of 10 and 12. The instructional intervention was conducted by one of the researchers, a female teacher with 15 years of professional experience, who is currently pursuing a master's degree in Curriculum and Instruction.

Data Collection Tools

As part of the research, a needs analysis was first conducted at the selected school. Based on the results of this analysis, a pretest and posttest were developed for the targeted unit. The achievement test was revised in line with expert opinions, and validity and reliability analyses were performed. During the test development process, expert evaluations were obtained regarding both the content and linguistic clarity of the items. The internal consistency of the instrument was calculated using the KR-20 coefficient, which yielded a value of .89. Since a reliability coefficient above .50 is considered acceptable for tests with fewer than 50 items, the test was deemed reliable. An item difficulty analysis revealed that most questions were of moderate difficulty, with a balanced distribution of easy and difficult items as well.

In order to identify an appropriate instrument for assessing the development of 21st-century skills, several existing scales were reviewed. Mete (2021) developed a 12-item skills scale specifically for middle school students. The comprehensive scale developed by Kalemkuş and Özek (2022), which includes 31 items measuring competencies such as creativity, communication, problem-solving, leadership, and media literacy, was examined in detail in terms of its suitability for the study content and participant group. Owing to its high overall reliability and internal consistency, this scale was selected for the study after obtaining the necessary permissions from the authors.

The scale developed by Kalemkuş and Bulut Özek (2022) was thus used to measure students' 21st-century skill levels. According to reliability thresholds indicated by Özdamar (2004) and Kalaycı (2014), scales or factors with Cronbach's alpha values between .60 and .80 are considered to have acceptable reliability. In this study, the scale demonstrated excellent reliability, with an overall Cronbach's alpha coefficient of .973 and sufficiently high values across its subdimensions. Based on these findings, the instrument was deemed valid and reliable for measuring the target skills and was implemented as both a pretest and posttest skill assessment tool in the research.

Data Collection Process

The school where the study was conducted serves students from economically disadvantaged backgrounds, has a low literacy rate among families, and predominantly relies on traditional instructional methods. Additionally, the institutional culture at the school is relatively underdeveloped. Prior to the implementation phase, meetings were held with school administrators, teachers, and students to conduct a needs analysis. Based on the results of this analysis, and with the input of science teachers, the instructional topic was selected, and an instructional plan aligned with the Understanding by Design (UbD) model was developed to cover a total of twenty class hours.

The Process of Developing a UbD-Based Instructional Design

A three-stage instructional design based on the Understanding by Design (UbD) model was developed for a total of twenty class hours, focusing on the learning outcomes outlined in the curriculum related to the "Human and Environment" unit. The process began with the formulation of a "Big Idea" under the theme: "You will truly live not on the day you spend to live, but on the day you let others live." Building on the general learning objectives in the curriculum, the design included targeted understandings, essential questions, knowledge goals, skill goals, and transfer goals.

In the second stage, assessment tools were developed to determine whether students had achieved the desired outcomes and, if so, to what extent. To evaluate summative performance, a RAFT-based task was utilized. For formative assessment throughout the process, various tools and techniques were employed, including 3-2-1 cards, "Three Truths and One Lie," collaborative writing tables, worksheets, posters, learning stations, self-assessment forms, peer evaluation rubrics, rating scales, and multiple-choice tests. During the performance task, each student completed a peer assessment form, and the rubric criteria were posted on the classroom board for transparency.

The final stage involved planning the delivery of instruction. This included clarifying what students would learn, why it was important, and what outcomes were expected; how attention would be captured and sustained; how students would be actively engaged; what learning experiences would be provided; how feedback and corrections would be offered; how individual differences would be accommodated; and how the sequence and structure of activities would be organized. After all three stages of the UbD framework were completed, expert feedback was solicited, and necessary revisions were made accordingly.

Implementation of the UbD Instructional Design

An experimental design with a pretest–posttest control group structure was employed in this study, involving two groups: the experimental group and the control group. Group assignment was conducted randomly and impartially to ensure objectivity. In order to compare results before and after the intervention, both groups were administered achievement and skills tests as pre-assessment tools.

The experimental group received instruction based on the UbD framework developed by the researcher-practitioner, implemented step by step over the course of twenty class hours. The control group, on the other hand, was taught by the same teacher over the same duration using the standard curriculum provided by the Ministry of National Education, with no instructional modifications.

Following the completion of the intervention, both groups were administered the same achievement and skills tests as post-assessments. The resulting data were then prepared for statistical comparison. Details of the implementation process are presented in the table below.

Table 1. Information Regarding the Experimental Procedure

Implementation Schedule	Pre-test Application Date	Intervention	Post-test Application Date
Experimental Group	26.03.2024	Understanding by Design (UbD) Implementation	20.05.2024
Control Group	27.03.2024	Standard Classroom Instruction	21.05.2024

Data Analysis

In order to address the research questions, the normality of the pretest and posttest scores for achievement and skills in both the experimental and control groups was first examined, and the results are presented in the table below.

Table 2. Results of Normality Tests

Scale	Group	Skewness (-1,5-1,5)	SE	Skewness/SE (-1,96 +1,96)
Achievement Test	Control Group - Pretest	0,45	0,43	1,03
		-0,74	0,85	-0,87
	Control Group - Posttest	0,27	0,43	0,62
		-1,37	0,85	-1,62
Achievement Test	Experimental Group - Pretest	-0,19	0,43	-0,45
		0,20	0,85	0,24
	Experimental Group - Posttest	-0,05	0,43	-0,11
		-1,07	0,85	-1,26
Skills Test	Kontrol Grubu Ön test	-0,04	0,43	-0,08
		-0,54	0,85	-0,64
	Kontrol Grubu Son test	-0,32	0,43	-0,74
		-0,78	0,85	-0,93
Skill Test	Deney Grubu Ön test	0,20	0,43	0,47
		0,15	0,85	0,17
	Deney Grubu Son test	-0,39	0,43	-0,90
		-0,36	0,85	-0,43

The fact that skewness and kurtosis values fell within the ±1.50 range (Tabachnick & Fidell, 2013), that the ratios of these values to their standard errors were within the ±1.96 limits, and that the significance level was $p > .05$ (Büyüköztürk, 2011) indicated that the test scores were normally distributed. Accordingly, independent samples t-test and paired samples t-test were employed in the analysis of the quantitative data.

The Role of the Researcher

In this study, the instructional designer who developed the twenty-hour UbD teaching plan also assumed the role of practitioner as one of the researchers. Throughout the research process, field notes were systematically recorded by the researchers through observations and interviews conducted before, during, and after the implementation phase.

Ethical Considerations

This research was conducted in adherence to the ethical principles required in scientific studies, and the necessary ethical approval was obtained from the Ethics Committee for Social and Human Sciences Research at Yıldız Technical University.

Limitations

Since the study was conducted in a single public school located in one province, the findings can be generalized only to groups with similar socio-cultural backgrounds. The study group consisted of 58 fifth-grade students attending a public middle school in Istanbul. The implementation was limited to the "Human and Environment" unit of the fifth-grade Science course during the second semester of the 2023–2024 academic year. UbD practices were applied solely within the scope of this unit. The duration of the study was limited to five weeks, which corresponds to the instructional period for the selected unit.

FINDINGS

Findings Related to the First Research Question

The analysis of the data regarding whether there was a significant difference between the pretest and posttest total scores of the experimental group on the achievement test is presented in the table below.

Table 3. Findings Related to the First Research Question

Experimental Group	N	X	SS	t	p
Pre-test	29	48,34	3,19	-6,50	.00
Post-test	29	62,93	3,55		

As shown in the table, the t-value was -6.50 and the p-value was less than .05, indicating a statistically significant difference between the experimental group's pretest and posttest total scores on the achievement test in favor of the posttest.

Findings Related to the Second Research Question

The analysis of the data regarding whether there was a significant difference between the pretest and posttest total scores of the control group on the achievement test is presented in the table below.

Table 4. Findings Related to the Second Research Question

Control Group	N	X	SS	t	p
Pre-test	29	49,61	2,87	-0,12	.91
Post-test	29	49,84	3,96		

As shown in the table, the t-value was -0.12 and the p-value was greater than .05, indicating that there was no statistically significant difference between the pretest and posttest total scores of the control group on the achievement test in favor of the posttest.

Findings Related to the Third Research Question

The analysis of the data regarding whether there was a significant difference between the posttest total scores of the experimental and control groups on the achievement test is presented in the table below.

Table 5. Findings Related to the Third Research Question

Group	N	X	SS	t	p
Experimental	29	62,93	3,55	2,46	.02
Control	29	49,84	3,96		

As shown in the table, the results of the independent samples t-test revealed a statistically significant difference between the posttest mean scores of the experimental and control groups ($t(56) = 2.46$, $p = .02$). This finding indicates that the difference favors the experimental group, demonstrating that the experimental group outperformed the control group in terms of academic achievement.

Findings Related to the Fourth Research Question

The analysis of the data regarding whether there was a significant difference between the pretest and posttest total scores of the experimental group on the skills test is presented in the table below.

Table 6. *Findings Related to the Fourth Research Question*

Experimental Group	N	X	SS	t	p
Pre-test	29	244,79	3,55	-6,39	.00
Post-test	29	262,34	3,54		

As shown in the table, the t-value was -6.50 and the p-value was less than .05, indicating a statistically significant difference between the pretest and posttest total scores of the experimental group on the skills test in favor of the posttest.

Findings Related to the Fifth Research Question

The analysis of the data regarding whether there was a significant difference between the pretest and posttest total scores of the control group on the skills test is presented in the table below.

Table 7. Findings Related to the Fifth Research Question

Control Group	N	X	SS	t	p
Pre-test	29	232,59	5,07	-1,65	.11
Post-test	29	237,14	5,81		

As shown in the table, the t-value was -0.12 and the p-value was greater than .05, indicating that there was no statistically significant difference between the pretest and posttest total scores of the control group on the skills test in favor of the posttest.

Findings Related to the Sixth Research Question

The analysis of the data regarding whether there was a significant difference between the posttest total scores of the experimental and control groups on the skills test is presented in the table below.

Table 8. Findings Related to the Sixth Research Question

Group	N	X	SS	t	p
Experimental	29	262,34	3,54	3,71	.00
Control	29	237,14	5,81		

As shown in the table, the results of the independent samples t-test revealed a statistically significant difference between the posttest mean scores of the experimental and control groups on the skills test ($t(56) = 3.71$, $p = .00$). This finding indicates that the difference favors the experimental group, demonstrating that the experimental group possessed a higher level of skills compared to the control group.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Discussion

The findings of this study indicate that the Understanding by Design (UbD) approach is an effective method for enhancing student achievement in the fifth-grade Science course. In particular, the significant increase in the posttest scores of the experimental group confirms the direct impact of the model on academic outcomes. This result supports the findings of Özdemir and Yurtseven (2021), who reported that the UbD approach positively influences both student achievement and learning motivation.

The significantly higher posttest scores of the experimental group compared to the control group indicate that the UbD approach is more effective than traditional teaching methods. This aligns with the findings of Uyguç (2022), who demonstrated that instruction based on the UbD model enhances students' conceptual understanding. These results suggest that UbD is effective not only in terms of academic achievement but also in promoting long-term retention and deeper conceptual learning. In classrooms where the UbD approach was implemented, students were observed to use higher-order thinking skills—such as problem-solving, inquiry, making connections, and interpretation—more actively. Their ability to critically examine the content through "why" and "how" questions highlights that this model supports not only academic achievement but also critical thinking and meaning-making skills (Altun & Yücel Toy, 2020). The lack of a significant difference between the pretest and posttest scores of the control group suggests that traditional instructional methods have limited impact on student achievement. This underscores the difficulty students face in experiencing meaningful learning when instruction is delivered through passive, teacher-centered approaches that limit student interaction and rely heavily on direct transmission of information.

A number of recent studies also support the positive impact of the UbD model on the development of 21st-century skills. For instance, research conducted by Yıldız (2021) and Kalemkuş (2023) reported that instructional environments structured according to the UbD approach led to significant improvements in students' communication, collaboration, creativity, and digital literacy skills. In addition, Tanrıöver (2022) demonstrated that STEM-supported UbD implementations had a positive effect on students' problem-solving abilities and metacognitive awareness. The significant difference observed between the pretest and posttest scores of the experimental group further indicates that the UbD model enhances students' knowledge levels. This finding is consistent with the results reported by Özdemir and Yurtseven (2021), whose study found that science instruction designed with the UbD model positively influenced students' academic achievement and motivation.

Another important observation made during the research process was that the teacher's proficiency in the UbD approach had a direct impact on the effectiveness of the implementation. The fact that the researcher also served as the implementing teacher contributed to stronger interaction with the students and facilitated the purposeful execution of the UbD plan. This finding highlights a direct relationship between teacher quality and the effectiveness of the instructional model. Moreover, the teacher's mastery of the UbD framework is considered a critical factor in the success of its application. The teacher who designed and delivered the instruction not only possessed theoretical knowledge of the model but also internalized its practice-oriented aspects, which positively influenced the students' learning processes. This result is also emphasized in the teacher experience–based study by Yurtseven and Doğan (2018). Overall, the findings suggest that the UbD model provides a comprehensive instructional framework that supports student-centered, meaning-focused, and skills-oriented educational approaches. In light of all these findings, it can be concluded that the UbD approach aligns with constructivist, understanding-based, and student-centered instructional principles, thereby making the teaching–learning process more effective.

Conclusions

This study examined the effect of science instruction structured through the Understanding by Design (UbD) approach on the academic achievement of fifth-grade students. Based on the findings obtained, the following conclusions were drawn:

A significant increase was observed between the pretest and posttest scores of the experimental group, indicating that the UbD approach had a positive impact on students' performance levels. The instructional process conducted through the UbD model led to a meaningful improvement in both the academic achievement and skill levels of students in the experimental group.

In contrast, no significant improvement was observed in the academic achievement of students in the control group, who were taught using traditional instructional methods. The absence of a significant difference between the pretest and posttest scores of the control group indicated that traditional teaching methods had a limited impact on students' achievement and skill levels.

When comparing the posttest scores of the experimental and control groups, a statistically significant difference was found in favor of the experimental group. This comparison revealed that students who received instruction through the UbD approach demonstrated higher levels of academic performance and skill development.

It was observed that students showed improvement not only in their knowledge levels but also in higher-order cognitive skills such as meaning-making, problem-solving, making connections, and inquiry.

These findings clearly demonstrate the positive impact of the UbD model on student achievement and show that the model contributes to student-centered instructional processes aligned with constructivist learning theories.

This study has shown that the Understanding by Design (UbD) approach is effective in enhancing both the academic achievement and 21st-century skill levels of fifth-grade students in science instruction. It was also found that the teacher's mastery of the UbD model had a direct impact on the success of the instructional process throughout the research.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

- The UbD approach should be implemented across different subject areas and various age groups to evaluate its effectiveness on a broader scale.
- Longitudinal studies should be conducted to assess the long-term impact of the UbD model on the development of 21st-century skills, which would help determine the model's lasting effects.
- Comprehensive professional development and in-service training programs should be provided for teachers to enhance their competence in implementing UbD practices.
- The implementation of the UbD model in schools with varying socioeconomic backgrounds should be investigated to explore its effects on disadvantaged student populations.
- Students' perspectives on their learning experiences within UbD-based instruction should be explored through qualitative methods to evaluate the model's perceived impact.
- Practice-based approaches such as UbD should be more widely incorporated into educational policy to support the expansion of constructivist instructional models.
- The long-term academic achievement and conceptual learning levels of students educated through UbD should be monitored to assess its effect on learning retention.
- The experiences of teachers who actively implement the UbD model should be investigated through qualitative research to identify strengths and weaknesses in the instructional process.
- These recommendations aim not only to improve science education, but also to provide a framework for the effective application of the UbD model across various disciplines.

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