



The Effectiveness of Understanding by Design Model in Science Teaching: A Quasi-experimental Study

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ABSTRACT

Purpose: Developing 21st-century skills and achieving learning outcomes in students' curriculum can only be accomplished through conscious and effective learning. Understanding by Design Model (UbD) is a model that aims to realise meaningful and permanent learning with student-centred practices based on understanding in teaching designs. This study aimed to examine the UbD model's effectiveness in primary school science teaching within the context of science achievement and permanence.

Research Methods: It was a semi-experimental study. The study group consisted of 40 primary school fourth graders studying at two distinct primary schools in Gaziantep in the academic year of 2019-2020.

There were 18 students in the experimental group and 22 students in the control group. While science teaching designed with Understanding by Design (UbD) model was adopted for the experimental group for five weeks, routine teaching practices were maintained for the control group. The science Achievement Test developed by the researchers was used to collect data. Research data were analysed using Mann Whitney U-Test and Wilcoxon Signed Ranks Test.

Findings: Research results indicated that the UbD model's adoption in science teaching positively affected students' academic achievements and the permanence of learning for the lesson under investigation. In light of the results, it was recommended to extend the effective use of the UbD in science teaching by providing primary school teachers with in-service training and prospective teachers with applied training within teacher training programs based on Understanding by Design. **Implications for Research and Practice:** The present study investigated the effect of the UbD on achievements and permanence for the cognitive domain. Future research may handle the effect of the UbD on learning in affective and psychomotor domains.

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Introduction

In this period, in which it is easier to access information as a result of the developments in technology, the main objectives of education include equipping individuals with the skills of accessing exact information rather than citing and developing the competence to use the knowledge and skills acquired by the individuals if necessary. It is crucial to develop 21st-century skills to achieve this end (P21, 2009b). Science can be regarded as one of the most convenient courses to provide students with 21st-century skills. It is hoped to equip students with scientific process skills and life skills such as analytical thinking, decision-making, creative thinking, entrepreneurship, communication and teamwork, engineering, and design skills like innovative thinking within this course's scope (MoNE, 2018).

Science, which is a lesson enabling questioning, inquiring, and examination practices by its nature, is also a field where high-level thinking skills are actively used, and the obtained information is associated with basic life skills (Cinar & Ilik 2013). One of the special purposes of this course, which aims to raise science-literate individuals, is to ensure that individuals take responsibility for their daily life problems and use knowledge, scientific process skills, and other life skills concerning science to overcome them (MoNE, 2018). The development of 21st-century skills and the achievement of learning outcomes can only be realised through conscious and effective learning through the four hours per week lesson given to the fourth graders. However, there is no single method or idea about how to supply conscious and effective learning in science education. The only consensus is that students should actively participate in the learning environment, regardless of the method or technique (Gencturk & Turkmen, 2007). It assigns teachers the responsibility to create and manage learning environments in which the students can achieve conscious learning and use what they have learned as their basic life skills. However, teachers may need guiding patterns or educational frameworks to create those environments and to plan and manage their teaching processes effectively.

The studies on science education in Turkey yielded that teachers' teacher-centred teaching habits have been prevalent in science education. The learner-centred methods, techniques and approaches have been exploited to a lesser degree. According to Bardak & Karamustafaoglu (2016), it was concluded that teachers used digital materials mostly through the use of smart boards during teaching and learning processes, and they usually exploited verbal teaching methods and techniques such as question-answer or discussion. However, it was unveiled that teachers rarely included active teaching methods and techniques such as role-playing, experimenting, and educational games (Bardak & Karamustafaoglu, 2016). Similarly, Karamustafaoglu, Baytar & Kaya (2014) also established that teachers often used direct instruction methods in science teaching and supported their teaching methods with the methods of question-answer, demonstration, case study, and problem-solving. However, they preferred student-centred discussions, laboratory, role-playing, and project-based learning methods to a lesser degree. Many studies have revealed that the use of learner-centred active learning methods and approaches in science teaching positively affect academic achievement, the lesson's attitude, and the permanence of learning.

For example; it was concluded that Web-based science teaching positively affected students' academic achievements and their attitudes towards the course (Cetin & Gunay, 2010), that simulation assisted science teaching had positive effects on students' achievements and their attitudes towards computer-assisted science teaching (Dagdalan & Tas, 2017), and that animation supported science teaching enriched with the strategy of (predict-observe - explain) positively affected students' achievements, their attitudes towards the lesson, and the permanence of information (Gokturk, 2015). It was uncovered that the implementation of the inquiry method for science teaching with the 4th graders in primary education (Gencturk & Turkmen, 2007; Ogreten, Ulucinar & Sagir, 2014) and teaching through game-based physical activities (Boyras & Serin, 2016) had positive effects on the academic achievement of students.

The low frequency of teachers' exploiting these approaches, methods, and techniques may not be stemmed from ignorance but from the problems in integrating them into the teaching process or their demand for alternative methods that are compatible with their teaching goals and teaching environments. In this regard, it is vital to scientifically test the effectiveness of different teaching approaches and models that support active learning and provide a framework that can guide teachers in integrating those teaching methods and techniques into the teaching process. Understanding by Design (UbD) can be considered a model that can guide teachers in organising learner-centred teaching. As the UbD is believed to be a useful instructional design in terms of enabling the transference of the acquired knowledge and skills to real-life, managing the process with the focus of understandings by providing a suitable environment by the teacher for active learning throughout the process could positively affect the attitudes of the learner (Gulsvig, 2009; Wiggings & McTighe, 2011).

The UbD is an instructional design model developed by Wiggings & McTighe (1998). The model is based on the 'understanding' of learners. 'Understanding' refers to the ability to adapt the information created by learners throughout the process for all new environments to be encountered, rather than understanding the information in lessons (Wiggings & McTighe, 2011). The instructional design in the UbD involves three stages. The first stage of the UbD is the desired results. Knowledge, skills, understandings, and essential questions are determined based on the given education (Wiggings & McTighe, 2011: 13). Understandings can be defined as the implications of big ideas intended to provoke the students to reflect on them (Wiggings & McTighe, 2011:80). In other words, understandings are the desirable permanent learning of students at the end of the educational process. Essential questions are those leading the students to search, discover, and contemplate issues. The answers to these questions with multiple responses often pose newer ones. Essential questions are related to real life and the situations that individuals may encounter in their work or daily lives (Wiggings & McTighe, 2011: 77). On the other hand, knowledge and skills are intended to be acquired by the students to learn the subject and use the min real-life environments.

In the second stage of UbD, assessment and evaluation methods and techniques are determined to evaluate the achievement of desired results identified at the first

stage, and the evidence is created. In other words, at this stage, it is aimed to determine what the measurable evidence will be for what students understand and achieve (Wiggins & McTighe, 2011: 17). Evidence is structured according to the six dimensions of understanding. In this context, evidence should be directed towards students' explanation, interpretation, new learning practice and gaining perspective, developing empathy, and self-recognition (Wiggins & McTighe, 2011: 94). Analytical rubrics, portfolios, main practice examples, self-evaluation forms, and performance tasks can be exploited to be evidence as well as other measurement instruments enabling diagnostic and process evaluation (Wiggins & McTighe, 2007: 101).

A learning plan is created for the third phase of the UbD. There are two types of elements when creating the learning activities included in the learning plan. The first group of elements tests learning activities' alignment with the desired results identified at the first stage of instructional design. The second group of elements (WHERE TO) guarantees that learning activities have the features required for student learning to be meaningful and permanent (Wiggins & McTighe, 2011). In short, it is aimed to contribute to the students' meaningful and permanent learning by giving them an active role during the teaching and learning process (with the instructional design based on the UbD model). The initial version of UbD model was submitted in Figure 1 below.

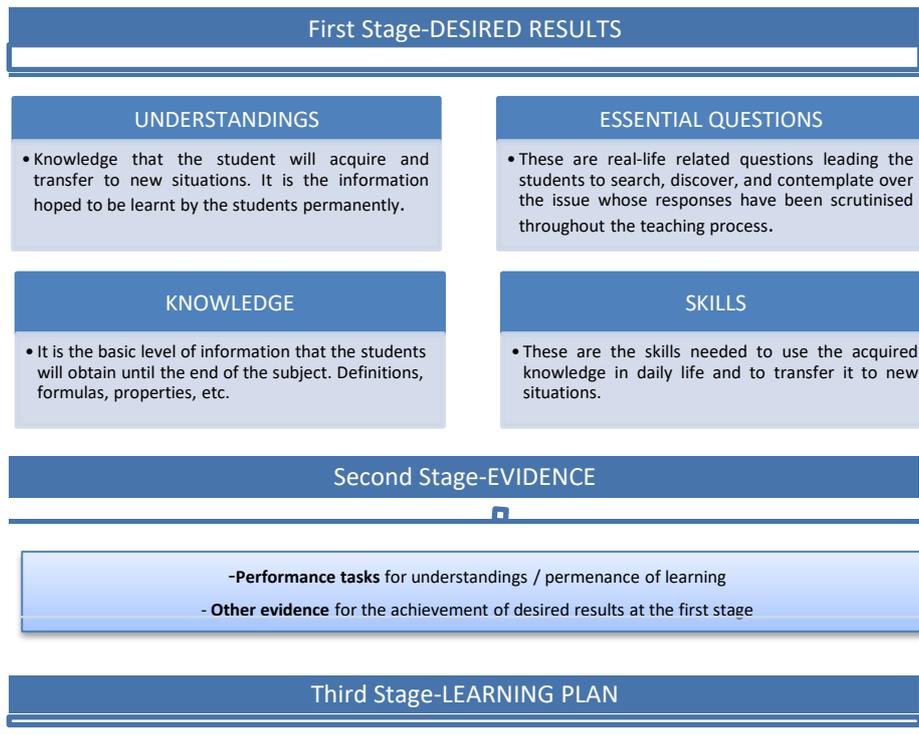




Figure 1. *The UbD Model Source: Wiggins &McTighe (2011: 16-17)*

As shown in Figure 1 above, the instructional design with the UbD focuses on the end of the teaching process. The backward design allows teachers to determine what and how they will teach after organising the process and how to evaluate them by transferring understandings and learning hoped to be achieved at the end of the education to the new situations (Wiggins & McTighe, 2011). Process monitoring has a significant place in the learner-centred learning plan created by the teachers on the subject (big idea), which is worthy of understandings to provide meaningful learning that is the focus of the UbD model. At this stage, whether learning activities/experiences are learner-centred and provide meaningful and permanent learning are tested with WHERE TO elements in addition to checking the alignment of learning activities with desired results. The expansion of the elements are as follows;

- W (where the unit is going): What do we learn, and what do we do about those learning?
- H (hold interest/hook): Engagement; How do we engage students, and how do we keep their curiosity alive?
- E (experience, equip, explore): Exploring; How do we get students to discover new information?
- R (rethink, revise): How do we ensure that students associate new knowledge with their previous learning? (rethink) and what should we do to correct misconceptions? (revise)
- E (evaluate): How do we evaluate learning?
- T (to be tailored): How do we handle individual differences?
- O (organise): Organising the learning plan for permanent learning and desired results (Wiggins & McTighe, 2005).

At this stage, each learning plan's learning activities are examined and listed within the model of "WHERE T", depending on the purpose of the activity. The abbreviation of "O" cannot be used for activities. It represents checking whether the learning plan is aligned with permanent learning and desired results with a student-centred approach and making the necessary arrangements. The ranking of WHERE T elements may vary according to the characteristics of the desired results at the first stage of the model and the students' interests and needs while organising the learning plan activities (Wiggins & McTighe, 2011). The learning plan must consist of learning activities with the necessary qualifications for the elements, and it should be organised accurately and effectively. Thus, WHERE TO elements ensure the teachers' provision

of learning experiences for the students in a planned, effective, and efficient way to realise understandings (Wiggins & McTighe, 2011).

It was observed that the effectiveness of the UbD had been investigated in literature in terms of learning, academic achievement, permanence, and attitudes towards the lessons of different educational levels (from pre-school to university-specific to a number of lessons). However, the effectiveness of the model was mostly addressed within the scope of language education in these studies, and it was determined that the implementation of the UbD in English teaching positively affected students' motivation to learn foreign languages (Yurtseven & Altun, 2017) and enhance their English-speaking skills (Arslan Buyruk, Erdogan, Cavusoglu Deveci & Yucel Toy, 2018). Moreover, the UbD model's implementation in pre-schools improved children's receptive language skills (Yurtseven & Dogan, 2018). Anderson (2012) and Duke (2011) also revealed that the implementation of UbD positively affected the development of students' reading skills. Similarly, the studies in which the effectiveness of the UbD was examined in different lessons revealed that the model had positive effects on academic achievements, permanence, and students' attitudes towards lessons. The UbD was found to encourage students to search and discover in history lessons (Schoellhorn, 2012) and to create a significant positive difference in their academic achievements in maths for the 10th graders (Acar, Ercan & Altun, 2019) and social studies teaching for the 8th graders (Noble, 2011).

The learning effectiveness of designing and maintaining teaching based on the UbD model has been tested by several studies (Anderson, 2012; Andrews, 2011; Arslan Buyruk, Erdogan, Cavusoglu Deveci & Yucel Toy, 2018; Bertram, 2011; Duke, 2011; Noble, 2011; Schoellhorn, 2012; Yurtseven, Dogan, & Altun 2013; Yurtseven & Altun, 2017; Yurtseven & Dogan, 2018). However, no specific study examining the model's effectiveness at the primary school level has been found in Turkish and English written literature. On the other hand, the available studies have revealed the effectiveness of the UbD mostly for non-maths related courses such as language education, reading, and social sciences. The effects of UbD on academic achievement, attitude, or permanence in science-oriented lessons were only examined in a limited number of studies. It was determined that applying the UbD model in science lessons significantly improved academic achievements, based on the studies which were mainly carried out in secondary schools (Kolenda, 2007; Rubrica, 2018; Yurtseven, Dogan & Altun, 2013). Therefore, it has been a matter of curiosity to scrutinise the model's effect on academic achievements and permanence at primary school science lessons. However, studies in Turkey have pointed out that teachers scarcely use learner-centred methods, techniques, and science teaching approaches (Bardak & Karamustafaoglu, 2016; Karamustafaoglu, Baytar, Kaya; 2014). Considering the potential of the model to provide a that can guide teachers in integrating learner-centred practices into the teaching process, it was deemed worthwhile to test the effectiveness of the UbD at different levels of education. The present study is also valuable because the obtained results may fill the literature gaps and provide practical information to teachers, administrators, and program developers.

In this context, the study's purpose was to examine the effects of science teachings designed with the UbD model on science achievements and permanence of fourth-grade students. The following research questions were sought;

1. Is there a significant difference between the experimental and control groups' gain scores for the science achievement test (pre-test and post-test)?
2. Is there a significant difference between the science achievement test scores (post-test) and the experimental and control groups' retention test scores?

Method

Research Design

This study investigating the effect of science teaching designed with the UbD model on science achievements and permanence of fourth-grade students was carried out in the pre-test-post-test semi-experimental pattern with experimental and control groups. This pattern is preferred in cases where it is difficult to synchronise experimental and control groups in terms of control variables in school structures (Gurbuz, Catlioglu, Birgin & Erdem, 2010) or in cases where it is difficult to form random groups (Grant & Pollock, 2011). The quasi-experimental study design was used in the study, as the experimental and control groups could not be assigned randomly. Students studying in pre-established two divergent classes with similar characteristics were determined as experimental and control groups.

Research Sample

The study was carried out with 40 students studying at two distinct public primary schools with similar characteristics in Sehitkamil District of Gaziantep in the fall semester of the 2019-2020 academic year. The experimental and control groups were chosen from two different schools to prevent possible interactions between students and teachers, which could have affected the results. There were projectors and computers in both schools' classrooms, and class sizes varied between 18-24 students. The participating students were the children of middle-income families. The student's parents did not receive a university degree, mothers were housewives, and fathers were usually craftsmen or farmers.

Research Instruments and Procedures

There were 18 students (13 boys, 5 girls) in the experimental group and 22 students (10 boys, 12 girls) in the control group. To match the experimental and control groups, similarities of their learning and teaching processes, demographics of the students (such as income levels or the educational level of their families), and the groups' mean of academic achievements were taken into consideration besides the equalness of their physical capacities and technological equipment of the schools.

The study's control group was a primary school teacher with 15 years of teaching experience and was not involved as a researcher. On the other hand, the experimental

group teacher had 5 years of teaching experience and was one of the present study's researchers (she is studying for a master's degree in a primary school teaching program). The teacher of the control group was male, while that of the experimental group was female. The control group teacher was determined to be a primary school teacher without prior knowledge about the UbD model and independent of the researchers to control the instructor's impact in the study.

Before the experimental study both teachers were interviewed to understand their routine practices regarding learning and teaching processes. Both teachers stated that they regularly followed the course book in science classes. The teachers also declared that they had the students note necessary information in their notebooks, maintained course book activities in the classroom, and they got the students to watch short films and activities from time to time using the EBA platform. Both teachers uttered that they frequently exploited the question-and-answer method. Teachers similarly voiced that they identified the weaknesses of students related to the subject matter through practice tests from the supplementary textbooks and that they attempted to overcome students' weaknesses through the practices of iteration within the scope of measurement and evaluation studies.

An ethics committee approval was applied before the implementation of the procedures. All participants were informed about the study's aim, and they agreed to participate in the study. The ethic committee approval (with documentation number 24850) was taken from Gaziantep University Social and Human Sciences Ethics Committee on 20.05.2020.

Research Instruments and Procedures

The researchers developed the Science Achievement Test (SAT) to measure the effect the UbD model has on students' academic achievements and permanence of learning. While developing SAT, which was applied as the pre-test, post-test, and permanence test, the fourth-grade science lesson curriculum was primarily examined, and the learning outcomes of the unit entitled "nutrients" were selected. Then, 25 multiple choice questions were prepared regarding the six learning outcomes of the unit. The questions, which were created based on the table of specifications by considering their distribution in terms of learning outcomes and taxonomy were submitted to the opinion of an expert faculty member in science education and two primary school teachers teaching fourth graders. Depending on expert opinions, a pilot form consisting of 25 items was finalised for the implementation after revising the distractors of two items and an item's wording. It was administered to 87 students studying in the fifth grade, where primary school graduates (of those under investigation) frequently enrolled in Gaziantep.

Following the instrument's administration, difficulty and discrimination indices of each item were estimated, the items with the discrimination index below .30 were eliminated. Moreover, the independent samples t-test was performed to uncover any significant differences between the upper and lower 27% groups. As a result of all these, five items were removed as they failed to ensure validity and reliability. The

distribution of the remaining 20 items by learning outcomes was consistent with their duration in the curriculum: the content density. Accordingly, eight of the 20 items were related to learning outcome1, two were with learning outcome2, three were with learning outcome3, three were with learning outcome4, four were with learning outcome5, and two were with learning outcome6. The KR-20 score of SAT consisting of 20 items was found to be .80.

Experimental Procedure

During the experimental procedure preparation phase, 15-hour intensive training was provided to the experimental group teacher about the theoretical framework of UbD, its reflections in instructional design, and its implementation at the primary school level. The theoretical framework of this training is based on Wiggins & McTighe (2005). "The primary school fourth-grade science curriculum was examined, and curriculum mapping was carried out based on the principles of Understanding by Design for the application phase of training. The training was supplied by an academic expert in Curriculum and Instruction, who teaches the UbD implementation in education at the Faculty of Education at Gaziantep University. Following the training, the unit entitled 'nutrients' of the fourth-grade science lesson was designed by the researchers (with the participation of the experimental group teacher) for 15 hours in 5 weeks based on the UbD. In this context, understandings, essential questions, knowledge, and skills were determined, assessment evidence was established, and WHERE TO elements and desired results were listed by creating learning activities for the learning plan. The creation of instructional design for the unit entitled 'nutrients' was rendered for the pilot scheme after submitting an independent expert's opinion with studies on UbD.

The pilot scheme's data collection process, pre-test, experimental procedure, post-test, and retention test included a 14-week period in the fall semester of the 2019-2020 academic year. During this process, the 6-hour (2-week) pilot scheme was primarily carried out by an experimental group teacher with a group of 21 students with similar characteristics for the instructional design, which was developed by researchers based on the UbD, reorganised according to the feedbacks of an independent expert and covering 15 lessons over five weeks. Before the pilot scheme, students were informed about the UbD and the purpose of the study. At the end of the pilot scheme, the aspects the students enjoyed, easily learned from, or had difficulties with were determined by receiving their opinions about the implementation. Additionally, the researchers observed the pilot scheme and evaluated the implementation and instructional design using the UbD Instructional Design Standards Rubric developed by Wiggins & McTighe (2011). Some activities were reorganised, as the number of activities included in the learning plan was determined to be redundant, and thus the time limit was exceeded. Moreover, instructions of some activities were rewritten to clarify student-teacher roles and purposes of activities as they were found to be ambiguous.

The procedures in the experimental and control groups were started simultaneously after the end of the pilot scheme. The experimental and control groups' teachers were first interviewed on what is expected of them during the process. The

control group teacher was asked to continue her routine practices and note regularly and thoroughly what he did for each lesson. The control group teacher's routine practices were monitored through his reports about the lesson and weekly interviews.

The experimental group teacher was asked to follow the learning plans developed for the implementation. The experimental group teacher also provided information to the researchers about the implementation process during weekly interviews following the lessons. After the preliminary preparations, the implementation of the experimental procedure was initiated. The implementation of the experimental procedure is given in Table 1 below.

Table 1

The Implementation of the Experimental Procedure

Groups	Pre-test	Experimental Process	Post-test	Retention
Control group	SAT	Routine practices	SAT	SAT
Experimental group	SAT	UbD practices	SAT	

As seen in Table 1 above, the pre-test was initially administered to both groups after the pilot scheme. Afterwards, a total of 15 hours of experimental procedures were conducted for five weeks, three hours per week. The post-test was administered to the groups immediately after the experimental procedure. Five weeks after implementing the post-test, the SAT was only administered to the experimental group to test its permanence.

Procedure in the Experimental Group

After the pre-test, the instructional design's implementation phase based on the UbD for the unit entitled 'nutrients' was initiated. At this stage, the learning plan that was finalised with arrangements based on the pilot scheme and expert opinion was maintained according to WHERE TO elements. In this regard, the students were informed about the objectives (desired results) and the learning activities to be used during the procedure at the beginning of the lesson (W).Afterwards, activities such as interesting questions, anecdotes, or short films addressing the relationship of the subject with daily life were used to arouse students' curiosity and draw attention to the subject (H).The students questioned essential questions, understandings, and knowledge in the instructional design through discussions, experiments, case studies, inquiries, and drama. It was attempted to create learning environments for 'e' students to explore knowledge (E₁).Thus, students were provided with the necessary knowledge and skills to complete their final assignments. Video and visual materials were used in each lesson plan to enrich the teaching procedure. The students were allowed to question their ideas and revise their learning through various discussion techniques to rethink and practice. Besides, possible misconceptions were prevented by giving students feedback and corrections (R).Process evaluation was employed with different assessment tools such as self-assessment, peer assessment, teacher

assessment, subject screening tests, performance tasks, structured grid, and concept maps exclusive to the subject to evaluate students' achievements of desired results (E₂). It was elaborated to diversify learning activities by considering individual differences, to use methods, techniques, and materials appealing to as many receptors as possible during the learning process and to ensure that the activities were inclusive of all students (I). In this regard, methods and techniques such as brainstorming, question-answer, case study, experiment, cooperative learning, project-based learning, and discussion were exploited, as well as individual and group work. The implementation lasted a total of five weeks and 15 hours, from 3 hours per week. The weekly practices of the spiral instructional design were explained below in general terms.

First Week: The learning plan created to achieve a total of 12 desired results, including understandings (3), essential question (3), knowledge (3), and skill (3). "Explains the relationship between the life of living beings and nutrient content." was followed this week, and student learning were tested through assessment evidence. While "The nutrients we consume in daily life have different benefits for our body." was an example of desired results of understandings, skills can be exemplified by "Consumes nutrients from all food groups in an amount that provides the energy required for a healthy life and in a balanced way." A total of 11 student-centred learning activities were implemented for those desired results. These learning activities included analogy familiar information for the unknown ones to help them find out that nutrients were sources of energy for the human body by posing the question of "When do you feel like a dead car, without energy?" Some of the evaluation evidence used during and after the teaching and learning processes were written and oral answers of the students to the questions, aiming to identify the implications about the covered subject (food diagrams which were grouped on being constructive-restorative, regulatory, or energising through listing the foods consumed for a week, and through subject screening tests).

Second Week: The learning plan created to achieve a total of 14 desired results, including understandings (3), essential question (4), knowledge (3) and skill (4) regarding the learning outcomes of "Explains the relationship between the life of living beings and nutrient content." and "Infers that water and minerals are present in all nutrients." was followed this week. The statement "All foods contain minerals and water" was an example of understandings, while "What foods meet your daily water needs?" exemplified essential questions. Experiment, brainstorming, aquarium technique, and role-playing were techniques used in student-centred learning activities this week. The second week's learning activities could be exemplified with brainstorming based on the question "Do all foods contain water?" and the experiment of "Which of the materials that the children brought to the classroom contains water?" An experiment report, word association test, student self-evaluations, and the teacher observation form were some of the evaluation evidence that was employed.

Third Week: A total of 18 desired results were addressed in the practices of the third week, including understandings (4), essential question (3), knowledge (6), and skill (5) regarding the learning outcome "Discusses the importance of the freshness and naturalness

of nutrients for a healthy life based on research data." together with those of the second week. While "It is important to check the expiration date and TSE sign before consuming pre-packaged foods for protecting our health." was an example of understandings, "How do you decide that the foods you consume are fresh?" exemplified essential questions. Moreover, "Extends the preservation period of any food that grows in their near environment by natural methods such as salting or drying." was a sample of desired results regarding skills. The learning plan included 11 student-centred learning activities for those desired results. These learning activities can be exemplified with brainstorming by asking, "How can we keep food fresh longer?" and then by evaluating the responses with student participation and teacher guidance. Another example was the practical implementation of natural salting and dry methods, which were used to extend the storage time of foods with small groups. In the concept map, answers given to the expansion and evaluation questions for students to express the implications of the subject and performance assignments to extend the preservation period with an appropriate method for the characteristics of the food (salting, drying, etc.) were some of the evaluation evidence that was exploited.

Fourth Week: The learning plan was followed this week for a total of 20 desired results, including understandings (2), essential question (4), knowledge (8), and skill (6) regarding the learning outcome "Relates human health with balanced nutrition." together with those of the first three weeks. While "Cooking the foods to be consumed with right methods increases their benefits to our body." was an example of understandings, "How does the consumption of more or less of any food affect our body?" exemplified essential questions. Moreover, "We should be careful to keep our food fresh and clean." was a sample of knowledge. Learning activities included a learning station, educational games, and digital teaching materials. One of the activities implemented this week was the game of 'Wonder What'. In this educational game, the student was given a crown. The image of the food was stuck on the crown so the student cannot see it. The student directed the question, "I wonder what I am?" to the classmates. Other students helped the student try to figure out what the food in the visual was, by telling the characteristics of the food. Peer assessment in the learning station and the questions included in homework papers were some of the fourth week's assessment evidence.

Fifth Week: The learning plan was followed this week for a total of 18 desired results, including understandings (2), essential question (3), knowledge (9), and skill (4) regarding the learning outcomes "Realises the negative effects of alcohol and smoking on human health." and "Takes responsibility to reduce smoking in their immediate surroundings." While "What problems may smoking and alcoholism cause in daily life?" was an example of essential questions, "Smoking damages many organs in our body, especially lung diseases." and "ALO 171 Smoking Cessation Hotline was established by the Ministry of Health in our country on the 27th of October 2010 to support those who want to quit smoking." Exemplified knowledge. Learning station, opposite-side panel, brainstorming, question and answer, and visual teaching materials for the effect of smoking on the lungs were used in learning activities. The evaluation evidence was composed of the learning station products, peer assessment included in that activity, the questions posed by the groups in the opposite-side panel and their answers and worksheets.

Procedure in the Control Group

On the other hand, the control group teacher taught the unit entitled 'nutrients' with his routine practices in this group for five weeks (15 hours). In this regard, the course book was followed in the control group, the learning activities included in the course book were exploited, and the students noted the necessary information in the book. Short films and activities were shown to students using the EBA platform. The texts related to the subject were studied from the course book, and students answered the questions in the book. Moreover, the teacher identified students' weaknesses related to the subject matter through practice tests in the supplementary textbooks, and the practices of iteration were performed to overcome those weaknesses.

Data Analysis

In data analysis, the Mann Whitney U-test was conducted to determine whether there was a significant difference between the groups based on the estimated gain scores by computing the difference between the pre-test and post-test scores of the experimental and control groups. Mann Whitney U-test replaces independent samples t-test when the data obtained from the studies with independent samples and a low number of participants in the experimental group followed nonparametric distribution (Buyukozturk, 2006). Wilcoxon signed ranks test was conducted to test the permanence of learning in the experimental group. The assumptions for parametric tests were tested in the study, and it was determined that the data set did not meet the assumption of normality. Therefore, the Mann Whitney U-test, the nonparametric equivalent of independent samples t-test, was used to determine the significant difference between the groups. Wilcoxon signed ranks test was conducted for permanence as the nonparametric equivalent of the paired sample t-test. The level of significance was accepted to be .01 for the interpretation of results.

Results

The results obtained from the Mann Whitney U test analysis used to determine whether there was a significant difference between the experimental group's gain scores with the UbD practices and the control group with routine practices for the science lesson unit 'nutrients', are given in Table 3 below.

Table 3

Mann-Whitney U-Test Results Regarding the Gain Scores of Experimental & Control Groups

Group	N	Mean Rank	Sum of Ranks	U	P
Experimental	18	28,31	509,50	57,5	,00
Control	22	14,11	310,50		

As shown in Table 3 above, there was a statistically significant difference between the SAT gain scores of the experimental and control groups favouring the former one

($U = 57.50$, $p < .05$). Accordingly, it can be alleged that science teaching with the UbD model was effective in terms of students' academic achievements.

The results obtained from the analysis of the Wilcoxon signed-ranks test with the post-test and permanence test achievement scores of the experimental group to determine the effect of science teaching with the UbD model on permanence were submitted in Table 4 below.

Table 4

Wilcoxon Signed Ranks Test Results Regarding the Permanence in Experimental Group

Permanence test	N	Mean Rank	Sum of Ranks	Z	P
Negative Rank	7	11,21	78,50	-,546 *	,585
Positive Rank	9	6,39	57,50		
Ties	2	-	-		

**Based on positive ranks*

As shown in Table 4 above, there were no statistically significant differences between the post-test SAT achievement scores of the experimental group with the UbD model and the retention test SAT achievement scores administered five weeks later ($Z = -,546$, $p > .05$). Thus, it can be asserted that science teaching with the UbD model yielded permanent learning for students.

Discussion, Conclusion and Recommendations

A significant difference was found between the experimental group with the UbD practices and the control group with routine practices in favour of the former one, based on gain scores in the present study investigating the effect of science teaching with the UbD model on science achievements and the permanence of learning for fourth-grade students. It can be regarded as an indicator that implementing the UbD model in science teaching effectively increases students' academic achievements. It is presumed that the enrichment of the learning-teaching process with student-centred learning activities based on WHERE TO elements and that the inclusion of all of the desired results identified within the framework of learning outcomes through the desired results elements may be influential on this result. Additionally, it can be alleged that ensuring students' active participation during the process and relating new learning to daily life through essential questions enable students to achieve meaningful learning based on their own experiences, which has improved achievement. That is why the implementation of discovery and inquiry-based learning techniques and the use of several student-centred teaching methods and techniques (such as brainstorming, discussion, drama, individual and group work, educational games, and learning stations) are guaranteed with the UbD model. The use of student-centred teaching methods and techniques in the learning-teaching process also enables meaningful and permanent learning. Additionally, the UbD implementation supports

the instructional development of teachers, and a broader and deeper understanding of content material is gained that can be passed to students, leading to both improved teaching and increased academic achievements based on the views of Bowen (2017), Groom (2010), Jordan Aldridge (2010) and Kolenda (2007).

The evaluation dimension of the UbD model also attempts to increase students' academic achievements. That is why assessments should consist of measurable evidence of how students achieve learning outcomes and achievements and how they gain scores (Wiggins & McTighe, 2011: 17). These pieces of evidence are structured according to six dimensions of understanding (Wiggins & McTighe, 2011: 94) and consist of process evaluation tools (Wiggins & McTighe, 2011: 101). There are also studies in the literature indicating that formative evaluation affects student success positively (Klute, Apthorp, Harlacher, Reale, 2017; Olina & Sullivan, 2002). Such assessments enable the teacher to determine each student's learning status without delay (Frunza, 2014) and the students to take responsibility in their own learning by self-assessment (Davies, 2002; Wiggins, 1998). In light of these, it can be alleged that the evaluation evidence contributes to improving academic achievement and supporting students' learning.

In line with the research results, research in the literature implies that the UbD model's implementation increases student achievements. Young (2005), Anderson (2012), Bertram (2011), Burson (2011), Duke (2011), Edmunds (2011), Noble (2011), Yurtseven & Altun (2018), and Snoke (2019) revealed that the implementation of the UbD model in teaching has positively affected student achievements. Similarly, Gulsvig (2009) pointed out that the UbD model is a tool for increasing student achievements when used to prepare a lesson or unit plan. Furthermore, Yurtseven, Dogan, & Altun (2013) found that implementing the UbD model in 6th-grade science teachings improved student achievements. Acar, Ercan, & Altun (2019) uncovered that implementing the UbD model in 10th-grade mathematics lesson did not produce a significant difference between the post-test success scores of the experimental and control groups; however, it significantly increased the post-test success scores of the students in the experimental group when compared to their pre-test scores. Similarly, Som, Turkan, & Altun (2016) ascertained that the model did not make a statistically significant difference in the pre-service teachers' achievement scores for the course of Introduction to Educational Sciences. However, these studies demonstrated that teaching with the UbD model activates students' positive affective characteristics and increases their active participation in lessons (Som, Turkan & Altun, 2016). The students have positive opinions about the implementation and contribution of the UbD model during the teaching process (Acar, Ercan & Altun, 2019). Moreover, teaching design with the UbD framework is effective in the development of teachers' teaching behaviours, according to Snoke (2019) and their professional development, according to Yurtseven & Dogan (2018).

It was also determined that there was no statistically significant difference between the post-test achievement scores and the retention test achievement scores of the experimental group with the UbD model. It indicates that the implementation of the UbD model is effective in creating permanent learning in science teaching. Research in

the literature reveals that the UbD model has positive effects in managing inquiry and critical thinking skills (Anderws, 2011; Boerger, 2005; Schoellhorn, 2012; Steffen, 2011). How this research results make a significant difference favouring the experimental group in terms of permanence can be seen. That is why inquiry-based learning is effective in realising meaningful and permanent learning (Gencturk & Turkmen, 2007; MoNE, 2018).

Additionally, it can be argued that the active participation of students in the process, from the beginning to the end, of learning and teaching processes (Brown, 2004; Yurtseven & Dogan, 2018) and the creation of learning activities considering individual differences through the 'T' element may also contribute to the permanence of learning. According to Keck & Kiney (2005), McCartney et al. (1997), and Sondergeld & Schultz (2008), the implementation of differentiated/ individualised teaching plans in teaching is effective in the permanence of learning and the transference of knowledge and skills acquired by students to real life. Similarly, Suarez (2007) noted that mathematics lessons planned with differentiated teaching encourage students' in-depth learning. In this context, it can be alleged that the UbD model effectively creates permanence of learning as it guarantees the inclusion of several practices that will provide meaningful and permanent learning into the learning plan with the WHERE TO elements.

To sum up, it was concluded that science teachings designed with the UbD model effectively increased the science achievement of fourth-grade students on the unit entitled 'nutrients' and ensuring new learning permanence. In light of these results, it is recommended to extend the effective use of the model in science teachings by providing in-service training to primary school teachers and applied training for prospective teachers within the scope of teacher training programs on the UbD model. This study is limited in investigating the UbD framework's effect on achievements and permanence for the cognitive domain. Future research may handle the effect of the model on learning in affective and psychomotor domains. Additionally, it is also important to examine the effect of using the UbD model during the teaching process on teachers and prospective teachers' teaching skill developments.

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Fen Bilimleri Öğretiminde Tasarım Yolu ile Anlama Modelinin Etkililiği: Yarı-deneysel Bir Çalışma

Atıf:

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Özet

Problem Durumu: Teknoloji alanındaki gelişmeler sonucu bilgiye ulaşmanın kolaylaştığı günümüzde eğitimin en temel amaçlarından biri de bilgiyi aktarmaktan ziyade doğru bilgiye ulaşma becerilerini bireye kazandırmak ve bireyin edindiği bu bilgi ve becerileri gereken durumlarda kullanabilme yetkinliği geliştirmektir. Bunun sağlanabilmesi için bireylerin 21. yüzyıl becerilerinin geliştirilmesi önem taşımaktadır. Fen bilimleri dersi öğrencilere 21. yüzyıl becerileri kazandırmak için en uygun derslerden biri olarak değerlendirilebilir. Bu ders kapsamında öğrencilere bilimsel

süreç becerileri, analitik düşünme, karar verme, yaratıcı düşünme, girişimcilik, iletişim ve takım çalışması gibi yaşam becerileri ve yenilikçi düşünme gibi mühendislik ve tasarım becerilerinin kazandırılması hedeflenmektedir (MEB, 2018).

Doğası gereği sorgulama, araştırma, inceleme çalışmalarına olanak sağlayan fen bilimleri dersi üst düzey düşünme becerilerinin aktif olarak kullanıldığı ve elde edilen bilgilerin temel yaşam becerileri ile ilişkilendirildiği bir alandır. Bütün bireylerin fen okuryazarı olarak yetişmesini amaçlayan bu dersin özel amaçlarından biri de bireylerin günlük yaşam sorunlarına ilişkin sorumluluk alınmasını ve bu sorunları çözmeye fen bilimlerine ilişkin bilgi, bilimsel süreç becerileri ve diğer yaşam becerilerinin kullanılmasını sağlamaktır. Dördüncü sınıflarda haftada dört saat verilen bu ders ile öğrencilerin öğretim programında yer alan 21. yüzyıl becerilerinin geliştirilmesi ve program kazanımlarına ulaşılması ancak bilinçli ve etkili öğrenmeler ile gerçekleştirilebilir. Ancak fen eğitiminde bilinçli ve etkili öğrenmenin nasıl gerçekleştirileceği konusunda tek bir yöntem ya da fikir bulunmamaktadır. Bu konudaki ortak görüş, yöntem ya da teknik ne olursa olsun öğrenme ortamında öğrencinin aktif olarak rol almasıdır. Bu durum öğretmenlere öğrencilerin bilinçli öğrenme gerçekleştirebilecekleri ve öğrendiklerini temel yaşam becerisi olarak kullanabilecekleri öğrenme ortamları oluşturma ve bu ortamları yönetme sorumluluğunu vermektedir. Ancak öğretmenlerin de bu ortamları oluşturup, öğrenme süreçlerini etkili bir şekilde planlayıp yönetebilmeleri için rehber niteliği taşıyan örnekler veya bir eğitim modeline ihtiyaç duymaları olasıdır. Çünkü son yıllarda Türkiye’de fen öğretimine ilişkin araştırmalar incelendiğinde öğretmenlerin fen öğretiminde öğretmen merkezli öğretim alışkanlıklarını sürdürdüklerini, mevcut öğrenen merkezli yöntem, teknik ve yaklaşımları sınırlı olarak kullandıkları görülmektedir. Tasarım Yolu ile Anlama (TYA) bu anlamda öğretmenlere rehberlik edebilecek bir model olarak ele alınabilir. Bununla birlikte alan yazında yer alan birçok araştırmada TYA modelinin öğrenme, akademik başarı, kalıcılık ve derse ilişkin tutumu olumlu yönde etkilediği belirlenmiştir. Ancak detaylı inceleme yapıldığında bu araştırmaların çoğunlukla dil eğitimi, okuma, sosyal bilimler gibi sözel derslerin öğretimini kapsadığı görülmüştür. Hem yurtiçi hem de yurtdışı alan yazında modelin etkinliğinin ilkökul düzeyinde fen bilimleri öğretimi bağlamında incelendiği bir araştırmaya rastlanmamıştır. Bu nedenlerden ötürü modelin ilkökul kademesinde ve ilkökul öğrencilerine fen bilimleri öğretiminde akademik başarı ve kalıcılığa etkisinin incelenmesi merak konusu olmuştur. TYA Modelinin, öğrenen merkezli uygulamaların öğretim sürecine entegrasyonu konusunda öğretmenlere rehberlik edebilecek bir çerçeve sunma potansiyeli de bu çalışmanın gerçekleştirilmesinde önemli bir unsur olmuştur. Araştırma, elde edilen sonuçların bu konudaki alan yazın boşluğunu doldurması ve öğretmenlere, yöneticilere ve program geliştirmecilere uygulamaya dönük bilgiler sunması yönüyle de değerli görülmektedir.

Araştırmanın Amacı: Bu araştırmanın amacı TYA modeli ile tasarlanan fen bilimleri öğretiminin dördüncü sınıf öğrencilerinin fen bilimleri dersi başarısına ve kalıcılığa etkisinin incelenmesidir. Bu çerçevede araştırma soruları şunlardır;

1. Deney ve kontrol gruplarının, ön-test ve sontest olarak uygulanan fen bilimleri başarı testleri puanları arasında anlamlı fark var mıdır?

2. Deney ve kontrol gruplarının, fen bilimleri başarı testi son-test puanları ile kalıcılık testi puanları arasında anlamlı fark var mıdır?

Araştırmanın Yöntemi: Araştırma deney ve kontrol gruplarını içeren öntest-sontest yarı deneysel desende gerçekleştirilmiştir. Araştırma 2019-2020 eğitim öğretim yılı güz döneminde Gaziantep ilinin Şehitkamil İlçesinde yer alan benzer özelliklere sahip iki devlet ilkokulunda öğrenim gören 40 öğrenci ile gerçekleştirilmiştir. Araştırmanın deney grubunda 18 (13 erkek, 5 kız), kontrol grubunda ise 22 (10 erkek, 12 kız) öğrenci yer almaktadır. Araştırmada veri toplama aracı olarak, TYA modelinin öğrencilerin akademik başarılarına ve kalıcılığa etkisini ölçmek amacıyla araştırmacılar tarafından geliştirilen Fen Bilimleri Başarı Testi (FBBT) kullanılmıştır. FBBT deneysel uygulamanın gerçekleştirildiği besinler ünitesine ilişkin 20 çoktan seçmeli maddeden oluşmaktadır. Ön test uygulanmasının sonrasında deney grubuna Besinler ünitesinin işlendiği beş hafta süresince toplam 15 ders saati TYA modeline göre hazırlanmış ders planları uygulanırken, kontrol grubunun aynı ünite için rutin uygulamaya devam etmesi sağlanmıştır. Deneysel işlem sonrası FBBT son-test olarak uygulanmış ve beş hafta sonra da kalıcılık testi olarak yeniden uygulama yapılmıştır. Gruplar arasındaki anlamlı farkın belirlenmesinde Mann Whitney U-testi kalıcılık için Wilcoxon işaretli sıralar testi uygulanmıştır. Sonuçların yorumlanmasında anlamlılık düzeyi .01 olarak kabul edilmiştir.

Araştırmanın Bulguları: Yapılan analiz neticesinde deney ve kontrol gruplarının FBBT erişim puanları arasında deney grubu lehine istatistiksel olarak anlamlı fark bulunmuştur ($U = 57,50, p < .05$). Buna göre TYA modeline göre yapılan fen bilimleri öğretiminin öğrencilerin fen bilimleri dersi akademik başarıları açısından etkili olduğunu göstermektedir. TYA modelinin uygulandığı deney grubunun son test olarak uygulanan FBBT başarı puanları ile beş hafta sonra kalıcılık testi olarak uygulanan FBBT başarı puanları arasında istatistiksel olarak anlamlı bir fark tespit edilmiştir ($Z = -.546, p > .05$). Bu bulguya göre de fen bilimleri öğretiminde TYA modelinin uygulanmasının öğrencilerde kalıcı öğrenme sağladığı söylenebilir.

Araştırmanın Sonuçları ve Öneriler: TYA modeli ile tasarlanan fen bilimleri öğretiminin dördüncü sınıf öğrencilerinin fen bilimleri dersi başarısına ve kalıcılığına etkisinin incelendiği bu araştırmada TYA modelinin uygulandığı deney grubu ile mevcut (rutin) uygulamalarla öğretim yapılan kontrol grubu arasında erişim puanlarına göre deney grubu lehine anlamlı fark tespit edilmiştir. Bu sonuç fen bilimleri öğretiminde TYA modelinin uygulanmasının öğrencilerin ders başarısını arttırmada etkili olduğunu göstergesi olarak kabul edilebilir. Bu sonuçta öğrenme öğretme sürecinin; WHERE TO kodlaması ile öğrenci merkezli öğrenme etkinlikleri ile zenginleştirilmesinin ve öğrenme çıktıları kodlaması ile kazanımlar çerçevesinde belirlenen tüm öğrenme çıktılarına kapsayıcı nitelikte olmasının etkili olduğu düşünülebilir. Ayrıca öğrencilerin sürece aktif katılımlarının sağlanmasının ve temel sorular ile yeni öğrenmelerin sorgulanarak günlük yaşam ile ilişkilendirilmesinin, öğrencilerin kendi deneyimlerinden yola çıkarak anlamlı öğrenmeler gerçekleştirmelerine olanak sağladığı, bunun da başarıyı artırıcı yönde etkileri olduğu söylenebilir. Çünkü TYA modeli ile deney grubunda çoğunlukla buluş ve araştırma- inceleme stratejilerinin uygulanması ve beyin fırtınası, tartışma, drama, bireysel ve grup çalışmaları, eğitsel oyun, istasyon tekniği gibi birçok öğrenci merkezli

öğretim yöntem ve tekniğın kullanılması garanti altına alınmıştır. Araştırmada ayrıca TYA modelinin uygulandıđı deney grubunun son test başarı puanları ile kalıcılık testi başarı puanları arasında istatistiksel olarak anlamlı bir fark bulunmadıđı tespit edilmiştir. Bu sonuç fen bilimleri öğretiminde TYA modelinin uygulanmasının kalıcı öğrenmeler gerçekleşmesinde etkili olduğunu gösterir niteliktedir.

Bu araştırmada TYA modeli ile tasarlanan fen bilimleri öğretimının, dördüncü sınıf öğrencilerinin besinler konusunda fen bilimleri dersi başarısını arttırmada ve yeni öğrenmelerin kalıcılıđını sağlamada etkili olduđu tespit edilmiştir. Bu sonuçlar ışığında; ilkokul öğretmenlerine hizmet içi eğitimlerle, öğretmen adaylarına öğretmen yetiştirme programları kapsamında TYA modeline ilişkin uygulamalı eğitimler verilerek, modelin fen öğretiminde etkin kullanımının yaygınlaştırılması önerilmektedir. Bu araştırma TYA modelinin bilişsel açıdan başarıya ve kalıcılıđa etkisinin belirlenmesi ile sınırlıdır. İleriki araştırmalarda modelin duyuşsal ve psikomotor alanlardaki öğrenmeler üzerindeki etkisi incelenebilir. Bununla birlikte öğretimde TYA modelinin kullanılmasının öğretmen ve öğretmen adaylarının öğretimsel beceri gelişimlerine etkisinin incelenmesi de önemli görölmektedir.

Anahtar Sözcükler: Kalıcı anlama, fen bilimleri öğretimi, akademik başarı, tasarım yolu ile anlama, ilkokul eğitimi.

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