Online Journal of Mathematics, Science and Technology Education (OJOMSTE)

Vol: 7 No: 1 Year: 2026

journal homepage: https://www.ojomste.com/index.php/1

Effects of Virtual Laboratory Applications on Academic Achievement and Six-Month Retention of Learning in Fourth-Grade Science Education*

Enis ABDİUSTA[a], *Ahmet ÜNAL*[b]

[a]*Kastamonu Universitesi, Institue of Social Science, Kastamonu/Türkiye*
e.abdiusta37@hotmail.com, https://orcid.org/0009-0002-6507-2286
[a]*Kastamonu University,Faculty of Education, Kastamonu/Türkiye*
aunal@kastamonu.edu.tr, https://orcid.org/0000-0001-8617-6602

Received: April 24, 2026 *Accepted: June 04,2026*

Keywords:

Science education,

virtual laboratory,

academic achievement,

simulation-based learning

Paper Type:

Research

Abstract

This study investigated the effects of virtual laboratory applications on fourth-grade students' academic achievement and learning retention in Science education. Utilizing a pre-experimental, single-group pretest–posttest design, instruction on the "Movements of the World" unit was delivered via the EBA portal and Mozaweb 3D simulation platform. The sample comprised 65 students from three public primary schools in Samsun, Turkey, selected through convenience sampling. Data were collected using a researcher-developed 10-item achievement test measuring knowledge, comprehension, and application. This instrument was administered as a pretest, an immediate posttest, and a six-month retention test—a notably longer delay than is typical in comparable literature. Statistical analyses revealed a significant improvement from pretest to posttest, demonstrating that virtual laboratory instruction successfully enhanced academic achievement. Furthermore, no significant decline was observed between the posttest and the six-month retention test, indicating highly durable learning. These findings demonstrate that simulation-based science instruction yields immediate and long-lasting educational benefits, providing valuable evidence for primary school contexts where research on virtual laboratories remains limited.

*This article was produced from the first author's master's thesis completed at Kastamonu University, Institute of Social Sciences, under the supervision of the second author.

Abdiusta, E., & Ünal, A. (2026). Effects of Virtual Laboratory Applications on Academic Achievement and Six-Month Retention of Learning in Fourth-Grade Science Education. *Online Journal of Mathematics, Science and Technology Education (OJOMSTE),* 7(1), 68-80.

Introduction

Science education aims to develop students' capacity to observe, question, and systematically analyze the natural world, while cultivating the scientific process skills and problem-solving abilities required for twenty-first century citizenship (Çepni et al., 2005; Duban, 2008). Alongside this pedagogical imperative, the increasing digitalization of education has generated both new opportunities and new research questions about how best to harness technology in service of meaningful science learning (Zacharia et al., 2008; de Jong et al., 2013).

One of the most significant developments in this landscape is the emergence and proliferation of virtual laboratory environments. Virtual laboratories are interactive, technology-mediated learning environments that allow students to conduct experimental simulations without the physical, financial, or safety constraints of traditional laboratory settings (Ünlü, 2019; Brinson, 2015). Interest in virtual laboratories has grown substantially since the COVID-19 pandemic compelled widespread adoption of remote and hybrid learning modalities, making their pedagogical effectiveness an increasingly urgent empirical question (Bostan Sarıoğlan et al., 2020; Kavlak ve Birhanlı, 2023).

A substantial body of research — predominantly conducted at the middle and secondary school levels — suggests that virtual laboratory applications may match traditional laboratory instruction in promoting conceptual understanding, scientific inquiry skills, and positive attitudes toward science (Kapici et al., 2019; Zacharia ve Olympiou, 2011; Tüysüz, 2010). Studies in the Turkish educational context have similarly found that virtual laboratories, particularly those accessed through the EBA national platform, promote achievement and engagement in science subjects (Ünal ve Şeker, 2020; Demir, 2018; Şimşek, 2017). However, systematic investigations of virtual laboratory effectiveness at the primary school level — where the conceptual foundations of science are first established — remain limited in the international literature (Akbulut, 2024; Baş, 2022; Ekici, 2015). This gap is noteworthy given that primary school students encounter abstract spatial and astronomical phenomena, such as Earth’s rotational and orbital movements, that are difficult to visualize through static textbook representations alone.

The present study was designed to address this gap. Grounded in constructivist learning theory and informed by cognitive load theory, it examined whether virtual laboratory instruction using the Mozaweb simulation platform, integrated within a structured lesson sequence aligned with the Turkish Ministry of National Education (MoNE) fourth-grade Science curriculum, would produce significant gains in academic achievement and long-term retention of learning. A distinctive feature of the study is its use of a six-month retention test, an interval substantially longer than the two-to-four-week delays typical in comparable studies, enabling a more robust assessment of the durability of learning gains.

Constructivism

This study draws on two theoretical frameworks: constructivism and cognitive load theory. The constructivist framework is used to explain the academic achievement gains observed from pretest to posttest, as students actively constructed knowledge through simulation-based inquiry. From a constructivist perspective, meaningful learning occurs when learners actively engage with phenomena, manipulate variables, and construct knowledge through exploration and discovery rather than passive reception of transmitted information (Vygotsky, 1978; Piaget, 1964). Virtual laboratories operationalize these principles by enabling students to interact with simulated environments, observe cause-and-effect relationships in real time, and revise their understanding iteratively through trial and error (Karagöz Mırçık, 2018; Ünal Koç, 2019). In the context of the Movements of the World unit, the Mozaweb simulation allowed students to directly manipulate

Earth's position relative to the Sun and observe the consequences for day-night cycles and seasonal variation, a form of concrete, vicarious experience not achievable through textbook or teacher-led instruction alone.

Cognitive Load Theory

Cognitive load theory (Sweller, 1988; Paas et al., 2003) is used to explain the six-month retention findings, as reduced extraneous load during instruction is expected to produce more durable mental representations. When abstract spatial concepts such as axial rotation and orbital revolution are represented through dynamic, interactive three-dimensional visualizations, extraneous cognitive load, the processing burden imposed by inadequate instructional representations, is reduced. Students can allocate more of their limited working memory capacity to germane processing: building integrated mental models of Earth's movements and their consequences. These richer, more elaborated representations are less susceptible to forgetting, which may explain why the learning gains observed in this study were maintained over a six-month interval.

Research Questions

The study addressed the following research questions:

RQ1. Do virtual laboratory applications in the Movements of the World unit produce a statistically significant improvement in fourth-grade students' academic achievement?

RQ2. Do the learning gains produced by virtual laboratory applications persist over a six-month retention interval?

Method

This study employed a pre-experimental, single-group pretest–posttest design (Campbell ve Stanley, 1963). Because the research was conducted in naturalistic school settings, random assignment to experimental and control conditions was not feasible. The design was chosen to balance practical accessibility of data collection with the opportunity to document change in the same participants across three measurement points spanning six months. The independent variable was the virtual laboratory-enhanced science instruction; the dependent variables were academic achievement (pretest–posttest comparison) and learning retention (posttest–retention test comparison). The primary limitations inherent in this design, notably the absence of a control group, are acknowledged explicitly in Section 6 (Limitations).

Participants

The study group consisted of 65 fourth-grade students (31 girls, 34 boys; mean age approximately 9–10 years) enrolled in three public primary schools in the Yakakent district of Samsun province, Turkey, during the 2023–2024 academic year. Participants were selected through convenience sampling based on the researcher's institutional access and prior ethics approval. Convenience sampling precludes claims of population representativeness; however, the comparability of the three school samples was empirically verified through a pretest ANOVA (see Section 3.1).

Table 1. Demographic Distribution of Participants Across Schools

School	Girls (n)	Boys (n)	Total (n)	% of Sample
School 1	18	15	33	50.8%
School 2	11	13	24	36.9%
School 3	2	6	8	12.3%
Total	31	34	65	100%

Measurement Instrument

The Movements of the World Unit Achievement Test was developed specifically for this study. The development process comprised five stages: (a) specification of learning outcomes, (b) item generation guided by a content validity table (Table 2), (c) expert review, (d) pilot administration, and (e) item analysis.

Table 2. Content Validity Table (Test Blueprint) — Movements of the World Unit

Learning Outcome	Bloom Level	Item Type	Item Numbers
Distinguishing Earth's rotation from revolution	Knowledge / Comprehension	Fill-in-the-blank	1, 2
Explaining formation of day and night	Comprehension / Application	Multiple choice	3, 4, 5
Explaining formation of seasons	Comprehension / Application	Multiple choice	6, 7
Identifying real-world consequences of Earth's movements	Application	Multiple choice / Fill-in-the-blank	8, 9, 10

The initial item pool contained 14 questions. Following expert review by two science education specialists and one classroom teacher — who evaluated items for content relevance, cognitive level appropriateness, and language clarity — two items were revised based on feedback. The revised 14-item test was then piloted with 71 fourth-grade students from the previous academic year. Item discrimination indices (D) were calculated for all items; four items yielding $D \leq .19$ were eliminated, resulting in a final 10-item test (five multiple-choice, five fill-in-the-blank). The Cronbach's Alpha internal consistency coefficient for the final test was .727, indicating acceptable reliability. Correct responses were scored as 1 and incorrect or blank responses as 0, yielding total scores on a 0–10 scale.

Instructional Procedure

All instructional activities were delivered by the researcher over nine 40-minute lessons, covering two MoNE curriculum outcomes: (F.4.1.2.1) distinguishing between Earth's rotation and revolution; and (F.4.1.2.2) explaining phenomena resulting from Earth's movements (day-night cycles, seasons).

The instructional sequence proceeded in three phases. In Phase 1 (Lessons 1–3), the MoNE-approved textbook provided the conceptual foundation, supported by teacher-led discussion and a riddle-based motivational opener. In Phase 2 (Lessons 4–6), content was deepened through the EBA (Education Information Network) portal, Turkey's national e-learning platform, which offered animated lesson explanations, interactive activities, and visual materials aligned with curriculum outcomes. In Phase 3 (Lessons 7–9), virtual laboratory activities were implemented using Mozaweb (www.mozaweb.com/tr), a three-dimensional simulation platform. Students individually manipulated Earth's axial position in the simulation environment, observed day-night formation as the planet rotated, and explored seasonal change across Earth's orbital revolution. They were encouraged to repeat the simulations as many times as necessary to confirm their understanding. Following the researcher-led sessions, the classroom teacher continued with the Mozaweb applications for an additional two weeks (six class hours) in accordance with the annual instructional plan. At the conclusion of instruction, the Mozaweb URL was shared with students so they could independently revisit the simulations at home.

Data Collection and Analysis

The achievement test was administered at three time points: (1) as a pretest before instruction, administered by classroom teachers, to establish baseline knowledge; (2) as a posttest immediately following the nine-lesson instructional sequence; and (3) as a retention test six months after the completion of instruction.

Normality was assessed by examining skewness and kurtosis values for each distribution. All three fell within the ±1 range considered acceptable for parametric testing (Hair et al., 2013): pretest (skewness = −0.26, kurtosis = −0.74), posttest (skewness = −0.83, kurtosis = +0.71), and retention test (skewness = −0.40, kurtosis = −0.45). Paired-samples t-tests were used to compare pretest with posttest scores (Research Question 1), and posttest with retention test scores (Research Question 2). A one-way ANOVA was conducted to verify the pre-instructional equivalence of the three school samples. All analyses were performed at $\alpha = .05$ using SPSS 26.

Results

Pre-Instructional Equivalence of School Samples

Prior to instruction, the overall pretest mean was M = 6.41 (SD = 1.96), with scores ranging from 2 to 10 (10-point scale). School-level means were 6.84 (School 1), 5.79 (School 2), and 6.50 (School 3). A one-way ANOVA confirmed that these between-school differences did not reach statistical significance ($F(2, 62) = 2.099$, $p = .131$), supporting the assumption that the three sub-samples entered instruction with comparable prior knowledge and validating their treatment as a unified study group.

Table 3. Pretest Descriptive Statistics and Between-School ANOVA

School	n	Min	Max	M	SD
School 1	33	2	10	6.84	1.91
School 2	24	2	10	5.79	2.19
School 3	8	5	8	6.50	1.19
Total	65	2	10	6.41	1.96

Effect on Academic Achievement (RQ1)

Following the virtual laboratory-enhanced instructional unit, the mean posttest score rose to M = 8.25 (SD = 1.33), with scores ranging from 4 to 10. This represents a raw gain of 1.84 points on the 10-point scale. Gender-disaggregated means were nearly identical (Boys: M = 8.23; Girls: M = 8.25), indicating no differential effect by gender. School-level posttest means were 8.51 (School 1), 7.91 (School 2), and 8.12 (School 3). A paired-samples t-test revealed a statistically significant improvement from pretest to posttest (t(64) = −9.42, p < .001), providing a clear positive answer to Research Question 1 (see Table 4).

Table 4.Paired-Samples t-Test: Pretest vs. Posttest

Comparison	n	M (Pre)	M (Post)	Mean Diff.	t	df	p
Pretest → Posttest	65	6.42	8.25	+1.83	−9.42	64	< .001

Effect on Long-Term Retention (RQ2)

Six months after instruction concluded, the same 65 students completed the retention test. This six-month interval is substantially longer than those reported in comparable research. The mean retention test score was M = 8.11 (SD = 1.48), with scores ranging from 4 to 10. The retention mean represents only a 0.14-point decline from the posttest mean of 8.25, well within the margin of measurement error. School-level retention means were 8.30 (School 1), 8.08 (School 2), and 7.37 (School 3). A paired-samples t-test comparing posttest with retention test scores found no statistically significant difference (t(64) = 0.90, p = .37), directly answering Research Question 2 in the affirmative: learning gains were preserved over the six-month interval (see Tables 5 and 6).

Table 5.Paired-Samples t-Test: Posttest vs. Six-Month Retention Test

Comparison	n	M (Post)	M (Ret.)	Mean Diff.	t	df	p
Posttest → Retention Test	65	8.25	8.11	−0.14	0.90	64	.370

Table 6.Summary of Score Trajectories Across All Three Measurement Points

Test Phase	n	M	SD	Min	Max
Pretest (T1)	65	6.41	1.96	2	10
Posttest (T2)	65	8.25	1.33	4	10
Retention Test (T3 — 6 months)	65	8.11	1.48	4	10

Discussion

Achievement Gains: A Cognitive Load Perspective

The statistically significant pretest-to-posttest improvement ($t = -9.42$, $p < .001$; $\Delta M = +1.83$ points) is consistent with a broad and growing literature demonstrating that simulation-based science instruction can enhance student achievement across grade levels and subject domains (de Jong et al., 2013; Brinson, 2015; Trundle ve Bell, 2010). Several studies conducted in the Turkish primary and secondary science context report comparable findings: Ünal and Şeker (2020) found virtual laboratory users outperformed traditionally taught peers in a fifth-grade electricity unit; Demir (2018) reported achievement gains in sixth-grade Force and Motion instruction; and Şimşek (2017) observed superior performance and greater lesson enjoyment among fifth-grade students using EBA and PhET simulations. A recent meta-analysis of 15 Turkish graduate theses similarly confirmed that virtual laboratory use in science education produces large positive effects on academic achievement (Ünal, İ., 2025).

The three-dimensional Mozaweb simulations likely reduced the extraneous cognitive load that arises when students attempt to mentally reconstruct spatial astronomical phenomena, such as Earth's axial tilt and seasonal variation, from flat, static textbook diagrams (Sweller, 1988; Paas et al., 2003). By offloading this representational burden onto the simulation, students could devote more working memory resources to germane processing: constructing integrated mental models of Earth's rotation and revolution and their observable consequences. This aligns with Mayer's (2009) Cognitive Theory of Multimedia Learning, which predicts that combining dynamic visualizations with interactive engagement produces deeper conceptual understanding than text or static imagery alone.

Achievement Gains: A Constructivist Perspective

The virtual laboratory also created a condition of active inquiry that is rarely achievable in traditional primary school science instruction (Vygotsky, 1978; Piaget, 1964). Students could directly test causal hypotheses, for example, positioning Earth at different orbital points to observe which hemisphere is tilted toward the Sun, and immediately observe the consequences, enacting the observe–hypothesize–test–revise cycle that defines scientific reasoning (Zacharia ve Olympiou, 2011). The ability to repeat simulations at will, at individual pace, and without resource constraints further supports differentiated learning (İçel et al., 2007; Ekici, 2015).

Not all research, however, finds virtual laboratories to be superior to traditional instruction. Aydın (2018) found no significant achievement gap between virtual and traditional laboratory conditions for an acid-base unit in secondary science, and Pınar and Akgül (2021) reported comparable motivation and attitude profiles across both laboratory modes among seventh-grade students. These mixed findings likely reflect heterogeneity in grade level, topic complexity, specific platform features, and implementation fidelity. The present study's topic — three-dimensional astronomical motion — may be particularly well suited to virtual simulation precisely because the phenomena involved are spatially complex, unobservable in the physical classroom, and difficult to represent through non-dynamic media (Trundle ve Bell, 2010).

Why Were Gains Retained Over Six Months?

The near-zero decline from posttest ($M = 8.25$) to six-month retention test ($M = 8.11$), a statistically non-significant difference ($t = 0.90$, $p = .37$), is the most notable finding of this study. Most comparable research employs retention intervals of two to four weeks (Duman ve Avcı, 2016; Chen et al., 2008; Küçük, 2014); the six-month interval used here provides a more stringent test of learning durability.

Several mechanisms may account for this persistence. The most plausible explanation lies in cognitive load theory: deeply elaborated mental models, built through interactive and multi-representational engagement, are more resistant to forgetting than surface-level declarative knowledge acquired through passive exposure (Sweller, 1988; Mayer, 2009). The spatial-causal understanding of Earth's movements that students developed through Mozaweb is a qualitatively different form of knowledge from the fact-level recall that typically decays rapidly. Two additional factors may have contributed, though neither was systematically measured. First, the astronomical phenomena studied, day and night cycles and seasonal change, recur in everyday life across the six-month interval, providing natural retrieval opportunities that may reinforce memory traces (Cepeda et al., 2006). Second, students received access to the Mozaweb URL for independent use after formal instruction. Duman and Avcı (2016) and Chen et al. (2008) similarly reported superior retention for virtual laboratory conditions, and the present study extends their conclusions to a primary school population and a more extended follow-up period.

Gender and School-Level Considerations

Gender comparisons across all three test administrations revealed virtually no difference in performance (pretest gap: 0.06 points; posttest gap: 0.02 points; retention gap: 0.53 points, with girls scoring slightly higher). This absence of gender effects is consistent with the broader literature on technology-enhanced science learning (Pınar ve Akgül, 2021) and suggests that virtual laboratory applications are equally accessible and engaging for boys and girls at the primary school level.

School-level pretest differences were not statistically significant ($F = 2.099$, $p = .131$), and all three schools demonstrated substantial posttest improvements, confirming that the intervention produced consistent achievement gains across different school contexts. The wider school-level variation observed at the retention test (range: 7.37–8.30) may reflect differences in how frequently classroom teachers continued to use the Mozaweb application after the researcher's sessions concluded — a variable that was not systematically monitored and that warrants attention in future research.

Conclusions and Practical Implications

This pre-experimental study provides evidence that virtual laboratory instruction using the EBA portal and Mozaweb simulation platform significantly improved fourth-grade students' achievement in the Movements of the World science unit, and that these gains were maintained at a comparable level six months later. These findings are consistent with the constructivist and cognitive load theoretical frameworks described in Section 1.1, and extend the virtual laboratory literature to the primary school level, a context in which such evidence was previously limited.

For classroom teachers, the results suggest that virtual laboratory applications — particularly freely accessible, curriculum-aligned platforms such as EBA — represent a practical and pedagogically effective strategy for teaching abstract astronomical concepts at the primary school level, even in resource-constrained settings. Teachers are encouraged to integrate simulation-based activities not merely as supplementary enrichment but as a core instructional phase, supported by deliberate sequencing from textbook-based concept introduction through interactive virtual exploration.

For school administrators and curriculum designers, the findings support investment in digital infrastructure and in providing teachers with training in virtual laboratory implementation. Incorporating virtual laboratory learning outcomes directly into annual instructional plans, and ensuring that adequate computer or tablet access is available, would facilitate wider adoption. The Ministry of National Education could extend the FATIH Project's scope to include the systematic pre-loading of vetted virtual laboratory applications onto school smart boards, removing access barriers for students in underserved communities.

The six-month retention finding warrants attention from school leaders: these findings may inform decisions about allocating limited technology resources toward simulation-based instruction.

Limitations and Future Directions

Several important limitations must be acknowledged when interpreting these findings. Most fundamentally, the results should be interpreted with caution due to the absence of a control group in the pre-experimental design, which means the observed achievement gains cannot be directly attributed to the virtual laboratory intervention. Alternative explanations cannot be ruled out: natural cognitive maturation, the instructional quality of the classroom teachers who continued the unit, increased general familiarity with the topic through everyday experience, or the motivational novelty of technology use (the so-called ‘Hawthorne effect’) could all have contributed to posttest gains independent of the specific affordances of virtual laboratory simulation.

A second limitation concerns sample size and generalizability. Sixty-five students from three schools in a single rural district of Turkey constitute a relatively restricted and potentially non-representative sample. Differences in school context, teacher quality, and family socioeconomic background were not systematically controlled for, and findings cannot be generalized to other populations, grade levels, or science topics without further empirical verification.

Third, the measurement instrument — a 10-item achievement test — offers only a narrow operational definition of learning. The test did not assess higher-order outcomes such as scientific reasoning, transfer of learning to novel contexts, or attitudes toward science, all of which may be differentially affected by virtual laboratory instruction. The absence of a Cronbach's Alpha above .80 also indicates that further test development would be beneficial.

Fourth, independent use of the Mozaweb application by students after formal instruction was encouraged but not systematically monitored, meaning it is unclear to what extent self-directed post-instructional practice contributed to the retention findings. Future studies should track out-of-school engagement with virtual laboratory platforms to disentangle instructional and self-practice effects on retention.

Future research should address these limitations by employing true experimental or quasi-experimental designs with randomized assignment or matched control groups; recruiting larger and more diverse samples across multiple districts and provinces; incorporating mixed-method data (e.g., interviews, observation) to understand students' cognitive and motivational experiences during virtual laboratory engagement; and examining the comparative long-term effectiveness of virtual versus traditional laboratory instruction within the same units. Longitudinal studies tracking cohorts across multiple science topics and academic years would provide the most definitive evidence regarding the conditions under which virtual laboratory instruction maximizes both achievement and retention at the primary school level.

References

Aydın, Ş. Z. N. (2018). *Fen bilgisi dersi öğretiminde sanal laboratuvar uygulamasının kullanılması ve değerlendirilmesi [Use and evaluation of virtual laboratory applications in science education]* (Unpublished master's thesis). İstanbul University, Turkey.

Akbulut, H. İ. (2024). Türkiye'de eğitim alanında sanal laboratuvar ile ilgili yapılan lisansüstü tezlerin içerik analizi: 2003-2023 [Content analysis of postgraduate theses on virtual laboratories in the field of education in Turkey: 2003-2023]. Dokuz Eylül Üniversitesi *Buca Eğitim Fakültesi Dergisi, 61*, 2017–2039. https://doi.org/10.53444/deubefd.1410659

Baş, K. (2022). *Fen eğitiminde sanal laboratuvar uygulamalarının öğrencilerin akademik başarılarına ve fen tutumlarına etkisi [Effects of virtual laboratory applications on academic achievement and science attitudes]* (Unpublished master's thesis). Akdeniz University, Turkey.

Bostan Sarıoğlan, A., Altaş, R., ve Şen, R. (2020). Uzaktan eğitim sürecinde fen bilimleri dersinde deney yapmaya ilişkin öğretmen görüşlerinin araştırılması [Teacher views on conducting experiments in science education during distance learning]. *Milli Eğitim Dergisi, 49*(1), 371–394.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers ve Education, 87*, 218–237. https://doi.org/10.1016/j.compedu.2015.07.003

Campbell, D. T., ve Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Rand McNally.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., ve Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin, 132*(3), 354–380. https://doi.org/10.1037/0033-2909.132.3.354

Chen, Y. C. (2008). Learning effects of virtual laboratory on conceptual knowledge and attitudes toward science. *Journal of Educational Technology ve Society, 11*(4), 120–136.

Çepni, S., Akdeniz, A. R., Ayas, A., Özmen, H., Yiğit, N., ve Ayvacı, H. Ş. (2005). *Kuramdan uygulamaya fen ve teknoloji öğretimi [Science and technology teaching from theory to practice]*. Pagema Yayıncılık.

de Jong, T., Linn, M. C., ve Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*(6130), 305–308. https://doi.org/10.1126/science.1230579

Demir, A. (2018). Endüstri 4.0'dan eğitim 4.0'a değişen eğitim–öğretim paradigmaları [Changing educational paradigms from Industry 4.0 to Education 4.0]. *Electronic Turkish Studies, 13*(15), 147–171.

Dönel Akgül, G., Geçikli, E., Konan, F., ve Konan, E. (2018). Fen eğitiminde sanal laboratuvar kullanımı hakkında öğretmen adaylarının görüşleri [Preservice teachers' views on virtual laboratory use in science education]. *Kesit Akademi Dergisi*, *14*, 61–74.

Duban, N. (2008). *İlköğretim fen ve teknoloji dersinin sorgulamaya dayalı öğrenme yaklaşımına göre işlenmesi: Bir eylem araştırması [Inquiry-based learning in primary school science: An action research study]* (Unpublished doctoral dissertation). Anadolu University, Turkey.

Duman, M. Ş., ve Avcı, G. (2016). Sanal laboratuvar uygulamalarının öğrenci başarısına ve öğrenilenlerin kalıcılığına etkisi [Effects of virtual laboratory applications on student achievement and retention]. *Erzincan University Journal of Education Faculty*, *18*(1), 13–33.

Ekici, M. (2015). *Fen bilimleri öğretmenlerinin sanal laboratuvar hakkındaki görüşleri ve bu yöntemden faydalanma düzeyleri [Science teachers' views on virtual laboratories and frequency of use]* (Unpublished master's thesis). Adıyaman University, Turkey.

Hair, J. F., Black, W. C., Babin, B. J., ve Anderson, R. E. (2013). *Multivariate data analysis* (7th ed.). Pearson.

İçelli, O., Polat, R., ve Sülün, A. (2007). *Fen bilgisi laboratuvar uygulamalarında yaratıcı proje desenleri [Creative project designs in science laboratory applications]*. Maya Akademi.

Kapici, H. O., Akcay, H., ve de Jong, T. (2019). Using hands-on and virtual laboratories alone or together — which works better for acquiring knowledge and skills? *Journal of Science Education and Technology*, *28*(3), 231–250. https://doi.org/10.1007/s10956-018-9762-0

Kavlak, E. E., ve Birhanlı, A. (2023). Fen bilimleri öğretmenlerinin COVID-19 uzaktan eğitim sürecinde sanal laboratuvar uygulamaları hakkındaki görüşlerinin incelenmesi [Examining science teachers' views on virtual laboratory applications during COVID-19 distance education]. *International Anatolia Academic Online Journal Social Sciences Journal*, *9*(2), 26–36.

Karagöz Mırçık, Ö. (2018). *Basit elektrik devreleri konusu ile ilgili kavramların öğretiminde sanal laboratuvar destekli 7E öğretim modelinin öğrencilerin zihinsel modelleri üzerindeki etkileri [Effects of the virtual laboratory-supported 7E model on mental models in electric circuits]* (Unpublished doctoral dissertation). Karadeniz Technical University, Turkey.

Küçük, T. (2014). *Işık ünitesinde simülasyon yönteminin kullanılmasının öğrencilerin fen başarısına ve fen tutumlarına etkisi [The effect of simulation use in the light unit on science achievement and attitudes]* (Unpublished master's thesis). Çanakkale Onsekiz Mart University, Turkey.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.

Paas, F., Renkl, A., ve Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, *38*(1), 1–4. https://doi.org/10.1207/S15326985EP3801_1

Piaget, J. (1964). Cognitive development in children: Development and learning. *Journal of Research in Science Teaching*, *2*(3), 176–186.

Pınar, M. A., ve Akgül, G. D. (2021). Sanal ve geleneksel laboratuvar uygulamalarının 7. sınıf öğrencilerinin kuvvet ve enerji ünitesiyle ilgili ders tutum ve motivasyonlarına etkisinin karşılaştırılması [Comparison of virtual and traditional laboratory effects on attitude and motivation]. *Akdeniz University Journal of Education Faculty*, *4*(2), 13–25.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive Science, 12(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4

Şimşek, F. (2017). Fen bilimleri dersinde animasyon ve simülasyon kullanımının öğrencilerin akademik başarısı ve bilgilerin kalıcılığı üzerine etkisi [Effects of animation and simulation use on academic achievement and retention in science]. *International Journal of Educational Science and Technology*, *3*(3), 112–124.

Taşkın, Ö. (2008). *Fen ve teknoloji öğretiminde yeni yaklaşımlar [New approaches in science and technology education]*. Pegem Akademi.

Trundle, K. C., ve Bell, R. L. (2010). The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Computers ve Education*, *54*(4), 1078–1088. https://doi.org/10.1016/j.compedu.2009.10.012

Tüysüz, C. (2010). The effect of the virtual laboratory on students' achievement and attitude in chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37–53.

Ünal, R., ve Şeker, R. (2020). Sanal laboratuvar uygulamalarının öğrenci akademik başarıları üzerine etkisinin incelenmesi: Elektrik ünitesi [Examining the effect of virtual laboratory applications on student achievement: The electricity unit]. *Kırşehir Journal of Education Faculty*, *21*(1), 504–543.

Ünal, İ. (2025). Fen eğitiminde sanal laboratuvar kullanımının öğrencilerin akademik başarılarına etkisi: Meta-analiz çalışması [The effect of virtual laboratory use on students' academic achievement in science education: A meta-analysis]. *Uluslararası Eğitim Bilim ve Teknoloji Dergisi*, *11*(1), 66–86.

Ünal Koç, İ. (2019). *Sanal ve gerçek laboratuvar uygulamalarının, 5. sınıf fen dersi elektrik ünitesi öğretiminde öğrencilerin akademik başarıları üzerine etkisinin incelenmesi [Effects of virtual and real laboratories on achievement in 5th grade electricity]* (Unpublished master's thesis). Necmettin Erbakan University, Turkey.

Ünlü, E. (2019). *Ortaokul fen bilimleri öğretmenlerin sanal laboratuvar kullanımının fen öğretiminde uygulanabilirliği hakkındaki görüşleri [Middle school science teachers' views on the applicability of virtual laboratories in science instruction]* (Unpublished master's thesis). Mersin University, Turkey.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Zacharia, Z. C., ve Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and Instruction, 21*(3), 317–331. https://doi.org/10.1016/j.learninstruc.2010.03.001

Zacharia, Z. C., Loizou, E., ve Papaevripidou, M. (2012). Is physicality an important aspect of learning through science experimentation among kindergarten students? *Early Childhood Research Quarterly, 27*(3), 447–457.

ETİK ve BİLİMSEL İLKELER SORUMLULUK BEYANI

Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara ve bilimsel atıf gösterme ilkelerine riayet edildiğini yazar(lar) beyan eder. Aksi bir durumun tespiti halinde OJOMSTE'nin hiçbir sorumluluğu olmayıp, tüm sorumluluk makale yazarlarına aittir. Yazarlar etik kurul izni gerektiren çalışmalarda, izinle ilgili bilgileri aşağıda belirtmişlerdir.

Kurul adı: Kastamonu Üniversitesi Sosyal ve Beşeri Bilimler Bilimsel Araştırmalar ve Yayın Etiği Kurulu

Tarih: 7.12.2023 No: 13/40

ARAŞTIRMACILARIN MAKALEYE KATKI ORANI BEYANI

1. yazar katkı oranı : %60
2. yazar katkı oranı : %40