

The Eurasia Proceedings of Educational and Social Sciences (EPESS), 2026

Volume 49, Pages 289-296

ICRET 2026: International Conference on Research in Education and Technology

The Effect of Simulation-Based and Traditional Teaching Methods on Student Achievement in 7th Grade Science Courses

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Abstract: The aim of this study is to examine the effect of the simulation method and the traditional teaching method, used in teaching the subject of electrical circuits in the 7th-grade Science course, on students' academic achievement. In the study, a pretest–posttest quasi-experimental design, one of the quantitative research methods, was employed. The study group consists of a total of 50 seventh-grade students studying at a private educational institution located in the Tepebaşı district of Eskişehir during the fall semester of the 2025–2026 academic year. Based on existing class levels, students were assigned to experimental and control groups, with 25 students in each group. In the experimental group, lessons were conducted using a simulation-based teaching method, while in the control group, lessons were carried out using the traditional teaching method. The “Electrical Circuits Achievement Test” was used as the data collection tool in the study. A pretest was administered to both groups before the implementation, and a posttest was administered after the implementation. The obtained data were analyzed using statistical methods. When the findings of the study are examined, it is concluded that simulation-based teaching practices significantly increased students' understanding of basic concepts, application and problem-solving skills, as well as their achievement scores. Furthermore, students who were taught using the simulation method achieved higher success compared to those who were taught using the traditional method.

Keywords: Science education, Educational technologies, Simulation supported teaching method, PhET

Introduction

Rapid developments in information and communication technologies significantly affect the structure of contemporary societies, and this transformation also yields notable outcomes in the field of education. With the process of digitalization, opportunities for accessing information have diversified, learning resources have become more accessible, and learning processes have transformed into more interactive structures. This change demonstrates that education systems cannot remain confined to traditional approaches and necessitates the cultivation of individuals who can adapt to changing social and technological conditions. Accordingly, the primary goal of educational institutions is to educate individuals who can follow scientific and technological developments, think critically, and possess multidimensional skills (Aybek & Aslan, 2015).

The integration of technological tools into learning environments makes instructional processes more flexible, interactive, and enriched. Through online platforms, interactive materials, and multimedia applications, students can access information through different channels and actively participate in the learning process. This indicates that learning is no longer a process solely based on knowledge transmission but has transformed into a student-centered structure that considers individual differences (Dağhan, Seferoğlu, & Esin, 2011). Moreover, technology-supported teaching approaches foster students' cognitive development, enhance their motivation toward learning, and particularly facilitate the comprehension of abstract concepts (Karadağ et al., 2019).

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- Selection and peer-review under responsibility of the Organizing Committee of the Conference

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Science courses are among the areas where technological tools can be effectively integrated into the instructional process. Technology-supported applications allow students to conduct experimental processes in safe environments, examine phenomena that are difficult to observe, and make abstract concepts more comprehensible (Şimşek & Hamzaoglu, 2020). In this context, simulations, animations, virtual laboratories, and other digital tools are important elements that support the learning process in science education (Çetinkaya Aydın & Çakiroğlu, 2021). Among these technological tools, simulations are particularly prominent in science education. Simulations enable the modeling of complex and abstract scientific concepts, supporting students in gaining a deeper understanding of the topics. Through these environments, students actively engage in the learning process, develop problem-solving and analytical thinking skills through trial and error, and improve their individual learning pace. This flexibility allows simulations to address students with different learning needs and positively affect their academic achievement (Bozkurt, 2008; Keskin, 2002; Dağdalan & Taş, 2017).

Science courses contribute to the development of scientific process skills by enabling students to actively participate in processes such as observation, experiment design, hypothesis formation, data collection, and analysis. An examination of the 2018 Science Curriculum reveals that learning outcomes enabling students to experience the research processes of scientists hold a significant place (MEB, 2018). In this respect, the literature frequently emphasizes that technology-enriched learning environments are effective in supporting students' cognitive development. In science education, technology-supported learning environments, particularly computer-based simulations, have become an important component of instructional design in recent years. Many studies emphasize that such applications enable students to visualize abstract concepts, conduct safe and repeatable experiments, and actively participate in the learning process. Simulation-based instructional approaches are compatible with the constructivist learning perspective and support students' active involvement in modeling, hypothesis generation, and experimental inquiry processes; thus, shifting the focus of instruction from knowledge transmission to the learning process itself (Rutten, van Joolingen, & van der Veen, 2012).

Meta-analytic studies and systematic reviews indicate that simulations generally have positive effects on academic achievement and conceptual understanding. However, it is also noted that the magnitude of these effects may vary depending on several factors such as duration of implementation, instructional context, type of simulation used, and assessment tools. Additionally, some studies report that simulation-supported instruction positively affects students' motivation and attitudes toward the course (Talan, 2021). Although studies on the use of simulations in science education are widespread, it is observed that research focusing specifically on the 7th-grade level and particularly on the "Electric Circuits" unit is limited. The topic of electric circuits is of particular importance as it represents a learning area in which students systematically encounter fundamental concepts such as current, resistance, and the working principles of circuits for the first time. The literature frequently emphasizes that students often experience misconceptions and have difficulty understanding abstract relationships in this unit (Sengupta & Wilensky, 2018).

The limited number of studies comparing the effectiveness of simulation-supported and traditional teaching methods in the Electric Circuits unit reveals the need for more comprehensive and comparative research in this area. In particular, experimentally examining the effects of simulation-based instruction on students' academic achievement and conceptual understanding is important in terms of providing concrete findings to guide instructional practices (Jaakkola, Nurmi, & Veermans, 2011). Furthermore, the limited number of studies comparing simulation-supported and traditional methods further increases the significance of the present study (Yılmaz & Eren, 2014).

Many studies in the literature indicate that the use of simulations in science education improves students' academic achievement (Aydoğan, 2019; Bayram, 2019; Sezgin, 2002). For example, Aydoğan (2019) found that a simulation-supported collaborative learning method increased students' academic achievement and positively influenced their attitudes toward science compared to traditional teaching methods. These findings suggest that simulation-based instructional approaches constitute an effective alternative in science education.

In this study, it will be examined whether there is a difference in the academic achievement levels between a group taught the Electricity Circuits unit of the 7th-grade science course using the simulation method and a group taught using the traditional method. The aim is to reveal the effect of simulation-based teaching approaches on students' achievement in science courses.

Method

Research Model

In this study, a quasi-experimental design with a pretest–posttest control group model was employed within the scope of quantitative research. The experimental group was taught using the simulation method, while the control group received traditional instruction. Students’ achievement levels in the subject of electrical circuits were measured before and after instruction using pretests and posttests. The obtained data were analyzed with statistical methods to determine differences between the groups. The “Electrical Circuits Academic Achievement Test,” which has been validated and found reliable, was used as the data collection instrument (Ersoy & Ergun, 2025).

The study group consisted of 7th-grade students enrolled in a private institution in the Tepebaşı district of Eskişehir during the fall semester of the 2025–2026 academic year. According to their current grade levels, students were assigned to the experimental and control groups, each consisting of 25 students, resulting in a total of 50 students. Homogeneity of the groups was ensured based on students’ academic achievement levels.

Data Collection Instruments

The “Electrical Circuits Academic Achievement Test” (Ersoy & Ergun, 2025) was used to measure the 7th-grade students’ achievement in the topic of electrical circuits. The test consists of 32 multiple-choice items. During its development, analyses yielded a Cronbach’s Alpha of 0.89, indicating sufficient reliability. Each correct answer was scored as 1 point, while incorrect or unanswered items were scored as 0, resulting in total scores ranging from 0 to 32. The test was administered as both a pretest and a posttest to both experimental and control groups under standardized conditions in the classroom by the researcher. The reliability of the test was reassessed during the study, and ethical guidelines were strictly followed.

Data Collection Procedure

Data were collected from two different 7th-grade classes in the study group during the fall semester of the 2025–2026 academic year. The data collection process was carried out by the researcher under the supervision of the class teacher. Permission was obtained from the relevant school administration, and both teachers and students were informed about the study. Data were collected in two stages: pretest and posttest, both using the “Electrical Circuits Academic Achievement Test” (Ersoy & Ergun, 2025).

The pretest was administered one week before the instruction, and the posttest was conducted after the completion of the instruction. The experimental group received simulation-supported teaching, while the control group was taught using the traditional method. The instructional process lasted four weeks, with two class hours per week. The test was administered in both groups under the same guidelines, in the classroom, and took approximately 35 minutes. Student responses were collected confidentially, and the data were used solely for scientific purposes. This arrangement allows other researchers to replicate the study under similar conditions.

Data Analysis

Quantitative data analysis techniques were employed to determine whether the simulation-supported instruction significantly affected 7th-grade students’ academic achievement in electrical circuits. Pretest and posttest scores of the experimental and control groups were analyzed using SPSS. An independent samples t-test was conducted on the pretest scores to determine the similarity of the initial levels, and another independent samples t-test was applied to the posttest scores to examine differences in achievement after the intervention. Cohen’s d effect size was calculated for the posttest analysis based on Cohen’s (1988) classification.

Descriptive statistics (mean, standard deviation, minimum and maximum values) were computed using SPSS, and potential data entry errors were checked through z-score analysis. Analysis results were presented in tables, and the level of statistical significance was set at $p < .05$. Only quantitative analyses were used in the study, and the reliability of the analyses was ensured through accurate data entry, appropriate assumption checks, and the alignment of statistical techniques with the research questions.

Results and Discussion

This section presents the findings related to the analysis of data obtained from the Electrical Circuits Academic Achievement Test for the experimental and control groups. To determine whether the academic achievement levels of the experimental and control groups in the topic of electrical circuits were equivalent prior to the intervention, the pretest scores were analyzed using an independent samples t-test. The results are presented in Table 1.

Table 1. Results of independent samples t-test for the pretest of the electrical circuits academic achievement test

Group	n	$\bar{X}$	SS	t	p
Control	25	12.88	4.28	-1.226	0.226
Experimental	25	14.44	4.71		

$p > .05$

An examination of the findings presented in Table 1 indicates that there was no statistically significant difference between the pretest scores of the experimental and control groups ($p > .05$). This suggests that the groups had equivalent baseline achievement levels prior to the intervention. To compare the academic achievement levels of the experimental and control groups after the intervention, the posttest scores were analyzed using an independent samples t-test. The results are presented in Table 2.

Table 2. Results of independent samples t-test for the posttest of the electrical circuits academic achievement test

Group	n	$\bar{X}$	SS	t	p
Control	25	19.52	5.56	-2.264	0.028
Experimental	25	22.96	5.18		

$p < .05$

The independent samples t-test results indicated a statistically significant difference between the posttest scores of the experimental and control groups ($t(48) = -2.264$, $p < .05$, Cohen's $d = 0.64$). This finding suggests that simulation-supported instruction had a moderate effect on improving students' academic achievement in the topic of electrical circuits.

A paired samples t-test was conducted to examine the change between the pre-test and post-test scores of the experimental and control groups regarding their conceptual understanding of basic concepts (bulb, switch, battery), the working principle of electrical circuits, their ability to distinguish between conductors and insulators, and their knowledge of constructing simple circuits. The findings obtained are presented in Table 3.

Table 3. Comparison of the pre-test and post-test scores of the experimental and control groups in terms of their levels of understanding basic concepts in the electrical circuits academic achievement test

Group	Test Type	n	$\bar{X}$	SS	t	p
Control	Pretest	25	7.60	2.31	-1.077	0.287
Experimental	Pretest	25	8.28	2.15		
Control	Posttest	25	10.24	1.76	-5.636	0.000
Experimental	Posttest	25	13.64	2.45		

$p < .05$

According to the findings presented in Table 3, a statistically significant increase was observed between the pre-test ($\bar{X} = 8.28$) and post-test ($\bar{X} = 13.64$) scores of the experimental group in terms of their level of understanding basic concepts ($p < .05$). This result indicates that simulation-supported instruction is effective in improving students' conceptual understanding. A paired samples t-test was conducted to examine the change between the pre-test and post-test scores of the experimental and control groups in terms of their application and problem-solving skills, and the findings obtained are presented in Table 4.

Table 4. Comparison of the pre-test and post-test scores of the experimental and control groups in terms of their application and problem-solving skills in the electrical circuits academic achievement test

Group	Test Type	n	$\bar{X}$	SS	t	p
Control	Pretest	25	6.40	2.04	-0.700	0.487
Experimental	Pretest	25	6.80	2.00		
Control	Posttest	25	9.28	1.72	-3.460	0.001
Experimental	Posttest	25	11.12	2.03		

$p < .05$

According to the findings presented in Table 4, the application and problem-solving scores of the experimental group increased significantly from the pre-test ($\bar{X} = 6.80$) to the post-test ($\bar{X} = 11.12$) ($p < .05$). This result indicates that simulation-supported instruction is effective in improving students' problem-solving and application skills. A paired samples t-test was conducted to examine the change in academic achievement between the pre-test and post-test scores of the experimental and control groups, and the findings obtained are presented in Table 5.

Table 5. Comparison of pretest and posttest scores of the experimental and control groups on the electrical circuits academic achievement test

Group	Test Type	n	$\bar{X}$	SS	t	p
Control	Pretest	25	12.88	4.28	-1.226	0.226
Experimental	Pretest	25	14.44	4.71		
Control	Posttest	25	19.52	5.56	-2.264	0.028
Experimental	Posttest	25	22.96	5.18		

$p < .05$

An examination of the findings presented in Table 5 shows that there was a statistically significant difference in the experimental group between the pretest ($\bar{X} = 14.44$) and posttest ($\bar{X} = 22.96$) scores in favor of the posttest ($p < .05$). In the control group, a more limited increase was observed. These results indicate that simulation-supported instruction was more effective in enhancing students' academic achievement.

The findings of this study suggest that simulation-supported instruction is an effective method for improving students' academic achievement in the topic of electrical circuits. The lack of a significant difference between the groups in the pretests indicates that the experimental and control groups started from a similar baseline. However, the experimental group's significant advantage over the control group in the posttest suggests that the observed improvement in achievement can be attributed to the instructional method used. This indicates that simulation environments help concretize abstract concepts, enabling students to better understand the subject and take an active role in the learning process.

Through PhET simulations, students can obtain data and findings as they would in a real laboratory, allowing them to make predictions, develop explanations, and experience scientific process skills through virtual applications. In this regard, simulations facilitate the comprehension of abstract concepts and support the learning process. The observed moderate effect size further supports that the method not only enhances academic achievement but also strengthens students' conceptual understanding.

Previous studies in the literature have similarly shown that simulation-supported applications increase achievement in science and allow students to structure their own learning through trial-and-error (Turan, 2012; İlyasoğlu & Aydın, 2014; Yeşilyurt & Eyecioğlu, 2021; Yılmaz & Eren, 2014). Technology-supported instructional methods have also been reported to improve students' achievement, class participation, and interest in science (Akbaba & Kılıç, 2022; Bakırcı & Kılıç, 2021; Timur & Taşar, 2021). In this study, simulations were observed to contribute not only to academic achievement but also positively to students' interest in science.

Overall, the findings indicate that simulation-supported instruction provides significant contributions to the teaching of electrical circuits. The visualization of processes, immediate feedback, and learner-centered environment provided by simulations are key factors in the effectiveness of this method. Accordingly, simulation-based instructional approaches hold significant potential in science education for enhancing both academic achievement and conceptual understanding.

Conclusion

The results of this study indicate that the academic achievement of 7th-grade students in the topic of electrical circuits can be significantly enhanced through simulation-supported instruction. The equivalence of the groups in the pretests supports the conclusion that the differences observed in the posttest scores are directly attributable to the use of simulations. The simulation environment facilitated the visualization of concepts, allowed students to engage in trial-and-error learning, and provided immediate feedback, thereby improving the quality of the learning process.

Additionally, technology-based learning environments were observed to positively influence students' interest in the subject, motivation, and attitudes toward learning. Based on these findings, simulation-supported

instruction can be considered an effective, applicable, and meaningful method for teaching experiential topics such as electrical circuits.

Recommendations

Based on the findings of this study, several recommendations are proposed regarding the use of simulation-supported applications in science education. The results indicated that simulations enhance students' academic achievement, positively affect their participation and motivation, help concretize abstract concepts, and promote learning through trial-and-error strategies. Therefore, it is recommended that similar simulation applications be regularly employed in the teaching of topics such as electrical circuits.

Additionally, it is important for teachers to incorporate more student-centered simulation activities into their lesson plans and to use simulations as an alternative or complementary tool to real experiments, especially in schools with limited experimental resources. Providing students with opportunities for free exploration and using feedback for pedagogical purposes can further enhance the effectiveness of the learning process. Considering that simulations increase students' interest and motivation, it is also recommended that technology integration in science education be systematically expanded, and that technological tools be deliberately planned in lessons.

For future research, it is suggested to investigate the effectiveness of simulations in teaching subtopics of electrical circuits as well as other abstract science topics, such as the particulate nature of matter, atomic models, sound, and light. Developing activities that use simulations in assessment and evaluation to identify conceptual misunderstandings, comparing effectiveness across different grade levels, and preparing environments where students can individually interact with simulations using computer labs or personal tablets/laptops, depending on school facilities, are also recommended for future studies.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPES journal belongs to the authors.

* In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics"

Conflict of Interest

* Authors declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

Funding

* The author declares that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Research in Education and Technology (www.icret.net) held in Konya/Türkiye on April 02-05, 2026.

* The authors thank the members of the conference committee who conducted the preliminary review of this article and the reviewers who contributed their feedback.

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To cite this article:

Atıcı, A.S., & Aslan, O. (2026). The effect of simulation-based and traditional teaching methods on student achievement in 7th grade science courses. *The Eurasia Proceedings of Educational and Social Sciences (EPESS)*, 49, 289-296.