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Research Article

Computer-assisted instruction with virtual reality: Exploring its impact on science learning and gender differences

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The purpose of this study was to investigate the impact of computer-assisted instruction [CAI], incorporating virtual reality [VR], on the academic achievement of 6th-grade students in Science courses. The research employed a quasi-experimental design with a pre-test and post-test control group. Lessons in both experimental and control groups were conducted according to the 5E instructional model. While the experimental group utilized CAI, including VR, the control group followed traditional teaching methods. The study involved 52 students at a public school in the eastern region of Türkiye. A researcher-developed achievement test on the Respiratory System was used as the primary data collection tool. Quantitative data were analyzed using descriptive statistics, dependent and independent *t*-tests, and the Mann-Whitney U test. Findings revealed that CAI significantly improved students' academic achievement in Science, whereas gender did not affect performance outcomes. In the experimental group, there was no significant difference in achievement between students with or without personal computers. However, unexpectedly, students in the control group with personal computers outperformed those without. The study highlights the effectiveness of CAI, including VR, in enhancing academic performance and underscores the importance of equitable access to technological resources. These findings have implications for education policymakers, teachers, and parents aiming to improve Science education quality and promote equal learning opportunities through technological integration.

Keywords: Computer-assisted instruction; Virtual reality; 5E teaching model; Instructional videos; Science education; Academic achievement

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1. Introduction

The integration of technology into education has transformed traditional instructional practices, creating new opportunities to enhance student learning outcomes. Among these innovations, Computer-Assisted Instruction [CAI] has emerged as a prominent approach, leveraging computer and internet technologies to deliver educational content. Defined as a teaching tool that uses computer technology to present information to students (Şeker & Kartal, 2017), CAI has been shown to support and often surpass traditional methods in improving academic achievement

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(Christmann & Badgett, 2000). In science education, CAI has gained particular attention for its ability to make abstract and complex concepts more accessible, engaging, and concrete for students (Demircioğlu & Geban, 1996; Yalçın & Çelikler, 2011).

Science education, particularly at the primary and secondary levels, faces persistent challenges. Students often struggle to grasp scientific concepts due to their abstract nature and cognitive complexity (Moore & Harrison, 2004; Tekkaya, 2003). Topics such as the respiratory system or digestion, frequently covered in middle school curricula, require students to visualize processes that are not directly observable (Carvalho et al., 2007; Pettersson et al., 2020). This difficulty often leads to misconceptions, low engagement, and poor academic performance (Parker & Heywood, 1998; Şeker & Kartal, 2017). Research consistently highlights that students' achievement in science courses, especially in disciplines such as physics and biology, falls below expectations across various educational levels (Akanbi et al., 2018; Ugwuanyi et al., 2019).

CAI, particularly through the use of dynamic visualization tools such as animations, simulations, and virtual reality [VR], offers a promising solution to these challenges. Unlike static visual aids, dynamic visualizations present information in an interactive, time-based format, making it easier for students to understand processes and relationships that change over time and space (Ainsworth & VanLabeke, 2004; Rieber, 1990). For example, animations can illustrate molecular interactions or organ functions, enabling students to conceptualize abstract phenomena in a more tangible manner (Dönmez-Usta & Ültay, 2022; Teplá et al., 2022). Studies confirm that animations significantly improve students' academic achievement, engagement, and retention of concepts in science courses (Bunce & Gabel, 2002; Harrison & Treagust, 2006).

In addition to visualizing complex topics, CAI supports experimentation in virtual environments. Virtual labs allow students to conduct experiments safely, eliminating the risks and resource constraints of physical laboratories (Rossoni et al., 2024; Yavuz & Akçay, 2017). Moreover, technologies like VR provide immersive learning experiences, helping students explore scenarios such as traveling through the human respiratory system or observing planetary motion (Makransky et al., 2020; Zhang & Wang, 2021). Such tools not only enhance conceptual understanding but also foster curiosity and interest in science, paving the way for more effective and inclusive science education (Ibáñez et al., 2014).

CAI aligns closely with the principles of Constructivist Learning Theory, which emphasizes active participation and knowledge construction rather than passive reception (Daşdemir, 2016; Demirer, 2006). One instructional framework that integrates CAI effectively within constructivist pedagogy is the 5E Instructional Model. The model developed by Bybee et al. (2006) organizes lessons into five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation. The 5E model supports the active revision of prior knowledge and promotes the construction of new understanding through meaningful interactions with instructional content. When combined with CAI, the 5E model creates a student-centered, interactive learning environment that leverages technology to enrich the educational experience (Ballone Duran & Duran, 2004).

Despite its benefits, the adoption of CAI in science education remains inconsistent. Research suggests that many schools lack adequate technological infrastructure or sufficient digital teaching materials (Güven & Sülün, 2012; Güvercin, 2010). Additionally, while studies overwhelmingly support the efficacy of CAI, some report no significant differences in student performance compared to traditional methods (Alegre, 2012; Rosali, 2020). These mixed findings underscore the need for further research exploring the conditions under which CAI is most effective, particularly in diverse educational contexts.

This study aims to contribute to the growing body of literature on CAI by examining its impact on the academic achievement of 6th-grade students in a science course. Specifically, it focuses on the "Respiratory System" unit, using CAI technologies such as animations and virtual simulations within the framework of the 5E instructional model. The study also investigates how gender and access to computers influence the effectiveness of CAI. By addressing these factors, the research seeks to provide insights into the role of technological tools in promoting equitable and high-quality science education.

The research questions guiding this study are as follows:

RQ 1) Does the CAI method affect the academic achievement of 6th-grade students in the science course?

RQ 2) Does the gender factor influence the achievement of 6th-grade students using the CAI method?

RQ 3) Does access to a computer affect the achievement of 6th-grade students using the CAI method?

By exploring these questions, this study aims to shed light on the potential of CAI to improve science education outcomes and address persistent inequities in access to educational resources. The findings will offer valuable implications for educators, policymakers, and researchers seeking to integrate technology into teaching practices effectively.

2. Method

In this study, a semi-experimental research design commonly used in educational research, namely the pretest-posttest control group design, was employed. In this design, a pretest is administered to groups prior to the treatment, a posttest is administered following the treatment, and during the treatment period, the experimental group receives the treatment while the control group does not receive any specific intervention (Campbell & Stanley, 2015; Cohen et al., 2002).

2.1. Study Group

The study group of the research consists of 52 sixth grade students studying in two different classes (Class 1 and Class2) with similar achievement levels and similar demographic characteristics at the secondary school where the first researcher works, using easily accessible sampling method. In the study, two equivalent groups were formed, with one randomly assigned as the control group and the other as the experimental group. Accordingly, 26 students (from Class 1) were designated as the experimental group, while 26 students (from Class 2) were designated as the control group. Table 1 provides a summary of the characteristics of the participants.

Table 1
Characteristics of the participants (N=26)

Group	*Sub Group*	*f*	*%*
Experimental group			
	Male	16	62
	Female	10	38
	Has a computer	10	38
	Does not have a computer	16	62
Control group			
	Male	12	46
	Female	14	54
	Has a computer	9	35
	Does not have a computer	17	65

As shown in Table 1, 16 (62%) of the participants in the experimental group were male students, and 10 (38%) were female students. Among the experimental group, 10 (38%) had access to a computer, while 16 (62%) did not. In the control group, there were 12 (46%) male students and 14 (54%) female students, with 9 (35%) having computers and 17 (65%) lacking computers at home.

2.2. Data Collection Tool

In the study, an achievement test focused on the Respiratory System topic within the Support and Movement unit of the Science curriculum was used as the data collection tool. The achievement test utilized in the research was prepared to assess students' pre-existing knowledge levels about the Respiratory System topic before the study and to measure their achievement levels at the end of the research. This test was administered as a pretest before the treatment to measure the difference in achievement among students and as a posttest after the treatment for both the experimental and control groups.

During the development process of this achievement test, initially, a 20-item multiple-choice test was developed by reviewing various sources in accordance with the objectives related to the Respiratory System topic. Care was taken to ensure that the questions in the achievement test were appropriate for students' levels and aligned with the objectives of the curriculum. For content validity, the questions in the test were examined by four experts, three of whom were Science teachers, and one was an academician specializing in this field. During this review process, the experts provided feedback on the nature of the test questions, their alignment with the curriculum and grade level, whether they covered the relevant unit, and whether they measured the intended learning outcomes. Necessary revisions were made to the test items based on the feedback received from the experts. Subsequently, for the reliability of the test, a pilot study was conducted with 54 seventh-grade students (a higher grade that had previously covered the relevant topics) in a middle school in the city center of a city in the eastern region of Türkiye. After the pilot study, item analysis of the test questions was conducted to determine item difficulty levels and discrimination indices (see Appendix 1 for item statistics).

Based on the item statistics from the pilot study of the 20-item test developed for the achievement test, 4 items with a discrimination value below 0.2 were removed. The KR-20 reliability coefficient for the remaining 16-item multiple-choice test was found to be 0.83 (see Appendix 2). Tests with a KR-20 reliability coefficient of 0.70 and above are generally considered reliable, though higher values are preferred (Nunnally & Bernstein, 1994). Therefore, the reliability of the achievement test was ensured. The final version of the achievement test, consisting of 16 items validated through reliability and validity studies, was used as both the pretest and posttest for the experimental and control groups.

2.3. Process

Before the treatment, the achievement test was administered as a pretest to both the control and experimental groups. Analysis of the data obtained after the administration of the pretest revealed that these classes were equivalent in terms of academic achievement. Accordingly, one of the sixth-grade classes was randomly assigned as the experimental group, and the other as the control group. At the end of the treatment, the achievement test was re-applied to the experimental and control groups as a posttest.

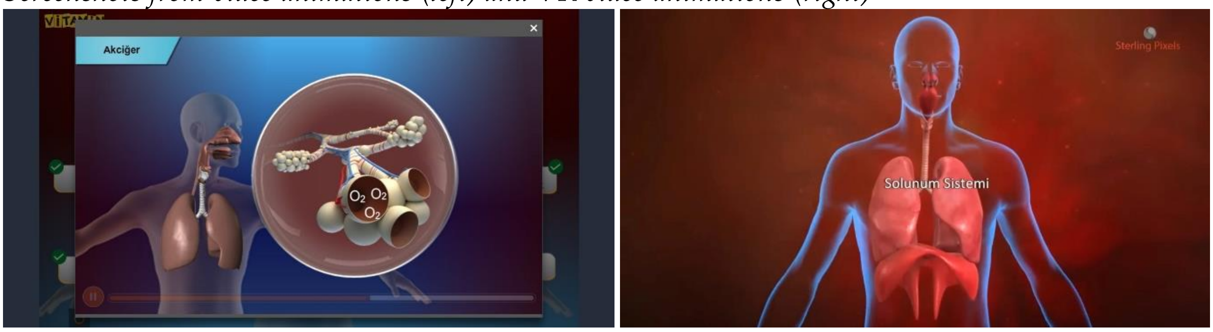
According to the 5E teaching model, lesson plans are structured to encourage students' active participation and in-depth learning. For the Engage phase, various teaching techniques and materials were used to attract students' attention, arouse their interest, and stimulate their curiosity. In this context, interesting questions about the Respiratory System were created and real-life examples were determined to be used with question-answer and discussion techniques. For the Explore phase, various materials were prepared for students in both groups to explore on their own and learn through experiments. In the experimental group, it was planned that students would explore the Respiratory System topic using computer-aided short videos and animations. In the control group, it was planned that the students would explore the subject through the activities in the textbook and workbook. For the Explain phase, various methods were determined for the teacher to clarify the topic and for students in both groups to explain what they had learned. In the experimental group, students were expected to make explanations through 3D animations using VR glasses. In the control group, it was planned that the students would explain what they learned from the textbook and be supported by the teacher's detailed explanations. For the Elaborate phase, various methods were considered for students in both groups to understand the information they learned more deeply and apply it in different contexts. In the experimental group, it was aimed for the students to deepen the subject and consolidate their knowledge through group work after watching the animations with the help of VR glasses. In the control group, it was planned that the students would deepen the subject through advanced questions and problems in the workbook. For the Evaluate phase, various methods were determined to evaluate students' progress in their learning processes in both groups. In both groups, the progress of the students was measured by using the achievement test as pre-test and post-test. These tests are planned to evaluate students' progress in the Respiratory System.

The application was carried out by the first researcher in accordance with the curriculum for a total of eight lesson hours in a two-week period. The lessons in the experimental group were taught in accordance with the lesson plans prepared according to the 5E teaching model in which the CAI method was applied. In the first week, the lessons were taught in the technology classroom with one computer for each student, while in the second week, the activities were presented to the students in the classroom environment through the use of VR glasses.

Figure 1
Students using VR headset in the classroom

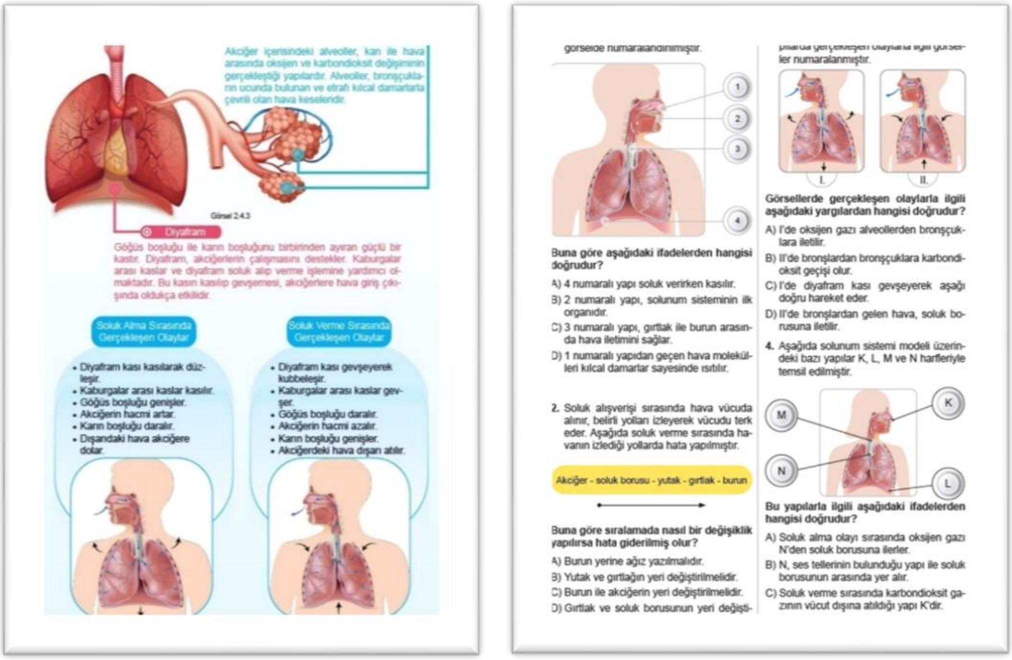
The activities during the course were carried out using 2D video animations and pictures on the computer in the first week, and in the second week they were carried out using a 3D video animation through VR glasses. There are 8 2D video animations and the duration of each is approximately one minute. 3D video animation is 6 and half minutes long.

Figure 2
Screenshots from video animations (left) and VR video animations (right)



The lessons in the control group were taught with the traditional method in line with the lesson plans prepared in accordance with the 5E teaching model. While carrying out the activities, the teacher benefited from the textbook and workbook and used a blackboard as well. The textbook and workbook are the official resources for the 6th grade students, published by the Türkiye Ministry of Education. The lecture process was carried out using a direct narrative method through a textbook and workbook containing illustrated explanations, as well as using other techniques such as question-answer and discussion.

Figure 3
Pages from textbook (left) and workbook (right)



2.4. Data Analysis

In the achievement test administered for the Respiratory System topic, the number of correct answers given by students was considered. Each correct answer was scored with one point, while incorrect and unanswered questions were scored as zero. The minimum score that could be obtained from the test is zero, and the maximum score is 16 points. If the data shows a homogeneous distribution as a result of the normality test, T-test is one of the parametric tests; If it did not show a homogeneous distribution, the Mann Whitney U test, one of the non-parametric tests, was preferred (Campbell & Stanley, 2015; Nunnally & Bernstein, 1994). While the *t*-test was used to compare the pre-test and post-test scores of the control and experimental groups, the independent *t*-test was used to compare the pre-test and post-test scores within the groups.

Additionally, Cohen's d coefficient was used to calculate the effect sizes of tests with statistically significant differences in the parametric tests (Cohen, 1988). According to Sawilowsky (2009), $d = 0.01$ means very low, $d = 0.20$ low, $d = 0.50$ medium, $d = 0.80$ large, $d = 1.20$ very large, and $d = 2.00$ means extreme effect size. In non-parametric tests, the r coefficient was used (King et al., 2018). The effect size is considered low when the value of r is around 0.1, medium when r is around 0.3, and large when r exceeds 0.5 (Cohen, 1988).

3. Findings

This part of the research includes descriptive statistics, normality tests and comparison tests of the findings related to the sub-problems. An examination of the descriptive statistics in Table 2 reveals that the test scores (correct answers) of the experimental group increased from 7.88 to 13.42. Similarly, the scores in the control group increased from 7.07 to 10.00. Normality tests were conducted to assess the significance of these observed differences and to determine the appropriate statistical tests for analyzing the effects of gender and computer ownership on the scores.

Table 3 shows the normality results.

Table 2
Descriptive statistics

			Pre-test		Post-test	
	f	%	*Mean*	*SD*	*Mean*	*SD*
Experimental Group						
Male	16	62	8.13	2.66	13.63	1.50
Female	10	38	7.50	3.89	13.10	2.13
Has a computer	10	38	8.70	3.59	13.30	1.95
Does not have a computer	16	62	7.38	2.80	13.50	1.67
Overall	26	100	7.88	3.12	13.42	1.74
Control Group						
Male	12	46	6.42	3.26	9.67	3.03
Female	14	54	7.64	3.39	10.29	2.61
Has a computer	9	35	7.89	3.33	11.11	3.37
Does not have a computer	17	65	6.65	3.33	9.41	2.29
Overall	26	100	7.07	3.32	10.00	2.77

Table 3
Normality test findings

	Kolmogorov-Smirnov			Shapiro-Wilk		
Groups	*Statistic*	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Experimental						
Pre-test	0.124	26	.2	0.952	26	.255
Post-test	0.206	26	.006	0.934	26	.095
Control						
Pre-test	0.121	26	.2	0.965	26	.49
Post-test	0.179	26	.031	0.943	26	.156
Experimental						
Pre-test						
Male	0.192	16	.119	0.963	16	.712
Female	0.216	10	.2	0.901	10	.224
Post-test						
Male	0.224	16	.031	0.92	16	.168
Female	0.164	10	.2	0.919	10	.348
Control						
Pre-test						
Male	0.187	12	.2	0.92	12	.289
Female	0.114	14	.2	0.977	14	.957
Post-Test						
Male	0.254	12	.032	0.919	12	.275
Female	0.173	14	.2	0.954	14	.63
Experimental						
Pre-test						
Has a computer	0.149	10	.200	0.930	10	.450
Does not have a computer	0.151	16	.200	0.943	16	.382
Post-test						
Has a computer	0.240	10	.106	0.935	10	.500
Does not have a computer	0.180	16	.175	0.952	16	.514
Control						
Pre-test						
Has a computer	0.181	9	.200	0.940	9	.579
Does not have a computer	0.166	17	.200	0.958	17	.597
Post-test						
Has a computer	0.271	9	.056	0.770	9	.009*
Does not have a computer	0.226	17	.021	0.938	17	.298

Note. * $p > .05$

The Normality Test results indicated that the data from the experimental and control groups, as well as their subgroups, followed a normal distribution based on the Shapiro-Wilk test (df < 30) for both pre-test and post-test scores, except for the post-test scores of the control group with a computer ($p > .05$). Accordingly, the dependent groups *t*-test, independent groups *t*-test, and Mann-Whitney U tests were employed to analyze the data.

3.1. Effectiveness of the CAI Method on Students' Science Achievement

The results of the dependent and independent groups *t*-tests, conducted to evaluate the achievement of the experimental and control groups based on their pre-test and post-test scores, are presented in this section. Table 4 presents the findings of the independent groups *t*-test for the comparison of pre-test scores.

Table 4
Independent groups t-test results for pre-test scores

Group	*N*	*Mean*	*SD*	*t*	*df*	*p*
Experimental	26	7.885	3.128	0.903	50	.371
Control	26	7.077	3.322			

The findings of the independent groups t-test comparing pre-test scores indicated no statistically significant difference between the experimental and control groups. Table 5 shows the comparison of post-test scores among groups.

Table 5
Independent groups t-test results for post-test scores

Group	*N*	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental	26	13.42	1.748	5.328	50	.371	0.25
Control	26	10.00	2.771				

The independent groups *t*-test conducted to compare post-test scores revealed a statistically significant difference between the experimental and control groups, favoring the experimental group. However, the effect size of this difference was low. While the statistical significance indicates a positive impact of the intervention on the experimental group, the practical significance or real-world impact of this difference appears to be modest. Table 6 shows the findings of dependent groups *t*-test for comparison of pre- and post-test scores.

Table 6
Dependent t-test results for pre- and post-test scores

	N	*Mean*	*SD*	*t*	*df*	*p*	*d*
Experimental							
Pre-Test	26	7.885	3.128	−11.59	25	.000	2.18
Post-Test	26	13.42	1.748				
Control							
Pre-Test	26	7.077	3.322	−4.487	25	.000	0.95
Post-Test	26	10.00	2.771				

The findings of the dependent groups *t*-test, conducted to compare the pre-test and post-test scores within the groups, revealed a statistically significant difference in favor of the post-test in the experimental group, with an excessive effect size. Similarly, a statistically significant difference in favor of the post-test was found in the control group, with a high effect size. However, the effect size in the experimental group was much larger than in the control group. This suggests that the treatment had a substantially greater impact on the experimental group than on the control group.

3.2. Impact of Gender on Students' Academic Achievement with the CAI Method

This section presents the findings of the independent groups *t*-test, conducted to examine the effects of the gender factor on the pre-test and post-test scores in the experimental and control groups. The findings from the independent *t*-test that explores how gender affects test scores are presented in Table 7.

Table 7
Independent t-test results on the impact of gender on test scores

	N	*Mean*	*SD*	*t*	*df*	*p*
Experimental						
Pre-test						
Male	16	8.125	2.655	0.488	24	.630
Female	10	7.500	3.894			
Post-test						
Male	16	13.63	1.500	0.738	24	.467
Female	10	13.10	2.132			
Control						
Pre-test						
Male	12	6.417	3.260	−0.936	24	.359
Female	14	7.643	3.388			
Post-test						
Male	12	9.667	3.025	−0.560	24	.581
Female	14	10.29	2.614			

Upon examining Table 7, it is observed that there is no statistically significant difference in the mean scores between the female and male groups in both the pre-test and post-test of the experimental and control groups ($p > .05$).

3.3. Influence of Computer Ownership on Students' Academic Achievement with the CAI Method

This section presents the findings of the independent groups *t*-tests and Mann-Whitney U test, conducted to examine the effects of computer ownership on the pre-test and post-test scores in the experimental and control groups. The independent groups *t*-test findings examining the effect of computer ownership on test scores are presented in Table 8.

Table 8
Independent t-test results on the effect of computer ownership on test scores

	N	*Mean*	*SD*	*t*	*df*	*p*
Experimental						
Pre-Test						
Has a computer	10	8.700	3.592	1.053	24	.303
Does not have a computer	16	7.375	2.802			
Post-Test						
Has a computer	10	13.30	1.947	−0.279	24	.783
Does not have a computer	16	13.50	1.673			
Control						
Pre-Test						
Has a computer	9	7.889	3.333	0.904	24	.375
Does not have a computer	17	6.647	3.334			

As shown in Table 8, it is observed that there is no statistically significant difference in the mean scores between the groups with and without a computer for both pre-test and post-test scores in the experimental group ($p > .05$). Similarly, for the pre-test scores of the control group, no significant difference was found between the groups with and without a computer ($p > .05$). Finally, Table 9 summarizes findings of the Mann Whitney U Test conducted to examine the effect of computer ownership on test scores.

Table 9
Mann-Whitney U Test results on the effect of computer ownership on post-test scores of control group

	N	*Mean Rank*	*Sum of Ranks*	*U*	*Z*	*p*	*r*
Control							
Has a computer	9	17.61	158.50	39.50	−2.013	.045	.48
Does not have a computer	17	11.32	192.50				
Total	26						

Table 9 shows a statistically significant difference in post-test scores between the groups of computer ownership favoring the group with having a computer. This difference had a medium effect size (U = 39.50; Z = −2.013; $p = .045$; $r = .48$).

4. Discussion

The purpose of this research is to examine the effect of computer-assisted instruction method on the academic achievement of 6th grade secondary school students in science course. Research findings evaluate the effect of the CAI method on students' academic achievement, as well as the role of gender and computer ownership factors on this achievement.

The research results indicate that the CAI method is effective in enhancing the academic achievement of 6th-grade students in science classes. In other words, implementing the 5E model using the CAI method in 6th-grade science classes yielded more successful outcomes compared to the traditional method. The pre-test and post-test results of the experimental and control groups reveal that the academic performance of students taught using the CAI method increased more than that of the control group. The video animations shown in the computer lab and the 3D animations viewed through VR glasses helped students understand the subject matter more effectively. These findings align with previous research demonstrating that CAI methods contribute more to students' learning processes than traditional teaching methods. For instance, Kahraman's (2007) study indicated that computer-assisted instruction positively affected students' academic achievement and improved their attitudes toward lessons. Busari et al. (2016) found that the CAI method significantly increased students' academic achievement in chemistry. Similarly, Suleman et al. (2017) reported that the CAI method enhanced students' performance in physics. The findings are also consistent with the study by Tabassum and Farooq (2011). Similarly, Teplá et al. (2022) showed that 3D models and animations positively impacted students' academic performance in science courses. These results demonstrate that CAI methods create positive effects across different subjects and student groups.

Furthermore, in this research, it was concluded that the CAI method is effective regardless of gender. In both the experimental and control groups, no significant achievement difference was found between male and female students. This result parallels previous studies indicating that gender does not have a significant impact on academic achievement. For example, Shen (1997) found that while male students' attitude were higher than females in computer science lessons delivered with CAI method, gender was not a determining factor in achievement. Busari et al. (2016) found no significant difference in the achievements of male and female students in chemistry lessons using the CAI method. Suleman et al. (2017) also found that the CAI method increased students' academic achievement regardless of gender. Ekundayo (2022) and Tabassum and Farooq (2011) stated that the CAI method was equally effective for both male and female students' achievement. However, some studies (Jacek, 1997; Wong et al., 2018) suggest that female students benefit more from the CAI method compared to male students. Jacek's (1997) study found that animations did not create a gender difference in long-term learning, but they particularly enhanced female students' performance. Wong et al.'s (2018) research revealed that spatial abilities and gender could significantly influence the effectiveness of CAI methods. Specifically, the study found that females may benefit more from animations compared to males. While these studies suggest that gender may have varying effects on the efficacy of CAI methods, such differences were not observed in our study. The different results may be explained by the diversity of research methodologies and learning environments. This highlights the need for further in-depth investigation into the effects of CAI methods on different learning environments and student groups.

The research results also reveal that having a computer at home does not significantly impact academic achievement in the experimental group. There was no statistically significant difference between students with and without computers in both pre-test and post-test scores. This finding aligns with Kahraman's (2007) study, which stated that students' computer ownership did not have a significant effect on academic achievement. However, in the control group, a statistically significant difference was found in favor of students who owned a computer in terms of post-test scores. This finding suggests that computer ownership may enhance achievement in traditional teaching methods but does not have the same effect when the CAI method is used. Similarly, Kılıç and Haşiloğlu's (2017) research revealed that socioeconomic status and computer ownership influenced students' academic achievement in traditionally taught courses.

5. Conclusion and Suggestions

This research demonstrates that the CAI method has the potential to enhance the academic achievement of 6th-grade students in science classes, while gender and computer ownership factors do not play a decisive role in this achievement. Additionally, it highlights that computer ownership positively contributes to students' academic achievement in traditional science classes, although the impact is limited.

The significance of this study lies in its demonstration of the effectiveness of the CAI method in increasing academic achievement in 6th-grade science classes. The findings also highlight the importance of technological infrastructure in ensuring equal educational opportunities. Widespread use of CAI methods via platforms like EBA can improve overall educational quality by making educational materials more accessible to students. Therefore, this study is important for supporting and promoting technology integration in education.

This study is also important for its contributions to various stakeholders. Education policymakers can use the findings to promote the widespread adoption of the CAI method and increase students' access to computers. This can guide the shaping of educational policies. Teachers can enhance students' academic achievement by incorporating the CAI method more in their classrooms. Parents can encourage computer use at home to support their children's educational processes.

Future research should delve deeper into the effects of CAI methods on different learning environments and student groups. Evaluating long-term effects is particularly important. Educators and policymakers should develop effective teaching strategies by making CAI materials more interactive and personalized. Additionally, providing the necessary technological infrastructure and ensuring teachers receive adequate training is crucial for maximizing the benefits of CAI methods. Students' access to technology should be considered when implementing CAI methods. Ensuring technological infrastructure and increasing students' access to computers at home is vital for ensuring equal educational opportunities.

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Appendix 1. Item statistics

Item	*Mean*	*Variance*	*Upper [T-F] (27%)*	*Lower [T-F] (27%)*	*Reliability*	*Difficulty (p)*	*Discrimination (r)*
Q1	0.87	0.11	15-0	9-6	0.14	0.8	0.4
Q2	0.59	0.25	15-0	3-12	0.4	0.6	0.8
Q3	0.52	0.25	13-2	5-10	0.27	0.6	0.53
Q4	0.89	0.1	15-0	9-6	0.13	0.8	0.4
Q5	0.74	0.2	15-0	4-11	0.32	0.63	0.73
Q6	0.83	0.14	15-0	7-8	0.2	0.73	0.53
Q7*	0.69	0.22	13-2	12-3	0.03	0.83	0.07
Q8	0.59	0.25	11-4	5-10	0.2	0.53	0.4
Q9	0.72	0.2	15-0	6-9	0.27	0.7	0.6
Q10	0.61	0.24	14-1	5-10	0.3	0.63	0.6
Q11	0.57	0.25	12-3	4-11	0.27	0.53	0.53
Q12*	0.56	0.23	10-2	12-3	0.03	0.87	0.06
Q13*	0.83	0.14	13-2	10-5	0.08	0.77	0.18
Q14	0.44	0.25	12-3	3-12	0.3	0.5	0.6
Q15	0.43	0.25	10-5	2-13	0.27	0.4	0.53
Q16	0.28	0.2	9-6	2-13	0.21	0.37	0.47
Q17	0.65	0.23	15-0	3-12	0.39	0.6	0.8
Q18	0.52	0.25	11-4	4-11	0.24	0.5	0.47
Q19	0.44	0.25	12-3	3-12	0.3	0.5	0.6
Q20*	0.7	0.21	13-2	8-7	0.15	0.7	0.13

Appendix 2. Item analysis findings

Number of Items	*N*	*Mean*	*σ2*	*Difficulty*	*Discrimination*	*K-20*
16	54	9.22	16.65	0.63	0.61	0.83