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Integrating Web 2.0 Tools into Science Teaching: Implications for Conceptual Understanding and Student Perspectives

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Article Info

Abstract

Article History

Received:
18 August 2025

Revised:
9 December 2025

Accepted:
18 January 2026

Published:
13 March 2026

Keywords

Conduction of electricity
Web 2.0
Conceptual understanding
Science education

The aim of this study is to develop a guiding material supported by Web 2.0 tools for the "Conduction of Electricity" unit in the 6th grade science course and to examine conceptual learning and student opinions about the process. The action research method, one of the qualitative research designs, was used in the study. The sample of the study consisted of 21 6th grade students. A Conceptual Understanding Test consisting of 15 open-ended questions developed by the researcher and a semi-structured interview consisting of 5 open-ended questions were used as data collection tools. According to the results of the Wilcoxon signed-rank test conducted on the conceptual understanding pre- and post-test scores, a statistically significant difference was obtained ($z=-4.02$, $p<.05$). After further analysis of the conceptual understanding test, it was determined that students made significant progress from the "No Understanding" level to the "Complete Understanding" level on the basis of all acquisitions; interactive and student-centered teaching practices supported by Web 2.0 tools strengthened conceptual understanding. In addition, student opinions reveal that Web 2.0 tools contribute positively not only to academic achievement but also to students' attitudes towards learning, class participation, digital competence, and interdisciplinary skills.

Citation: Tirnakcioglu, H. & Yildirim, N. (2026). Integrating Web 2.0 tools into science teaching: Implications for conceptual understanding and student perspectives. *International Journal of Technology in Education and Science (IJTES)*, 10(2), 275-294. <https://doi.org/10.46328/ijtes.5498>



ISSN: 2651-5369 / © International Journal of Technology in Education and Science (IJTES).
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Introduction

People's need for communication and information sharing is growing rapidly in the modern era, which is sometimes referred to as the information age. Rapidly developing technical advancements have started to be used in education as instruments that can satisfy these demands in recent years. Social networks have developed into communication platforms that incorporate both visual and aural components because of the extensive use of technology and the internet (Ekemen, 2022). The use of technology in the classroom has become increasingly significant in this setting. Technology-based instruction has many benefits over traditional teaching techniques, including increasing student engagement, improving material accessibility, and grabbing their attention. According to a study by Akbaba (2019), students' interest in science and their attitudes toward technology use were positively impacted by science instruction aided by Web 2.0 technologies. Similar results have also been documented in the literature (Arslan & Yildirim, 2021; Can, 2021; Köse et al., 2021; Sarı, 2019; Yildirim, 2020). For these reasons, it is observed that investments allocated to the use of technology in education in Türkiye have increased since the 2010s. The equipping of educational environments with technological tools can be cited as an example of this trend. Through the FATİH Project, initiated by the Ministry of National Education (MoNE) in 2010, classrooms were provided with specific infrastructure, and educational content was enriched through the establishment of web-based platforms. Subsequently, in 2022, various updates were introduced to the Education Informatics Network (EBA) system by the Ministry of National Education, with the EBA Academic Support module being restructured to incorporate content aimed at supporting students' individual learning processes. In the same year, the nationwide expansion of interactive whiteboards in secondary schools and high schools continued, and digital content platforms were developed by the Directorate General of Innovation and Educational Technologies (YEĞİTEK) of the MoNE and made available for teachers' use (Önal, 2022).

An examination of the Türkiye Century Maarif Model, introduced through changes made in 2024 and implemented in 2025, reveals that one of the objectives of science education is to cultivate individuals who can adapt to evolving technologies and are aware of digital transformation. The Science Curriculum aims to enable students to comprehend scientific developments within the context of digital transformation, adapt to technological innovations, and use technology effectively with an awareness of environmental responsibility. An analysis of the program's content indicates that teachers are expected to prepare in advance for relevant digital content and activities before commencing lessons. Furthermore, in cases where digital content is not directly available for learning, the program emphasizes the importance of integrating models, visuals, animations, and simulations into the learning environment (MoNE, 2024). In the teaching process, Web 2.0 tools can make a significant contribution to achieving these objectives. This is because Web 2.0 tools make the learning process more engaging, ensure active student participation, and foster interactive learning environments. Therefore, integrating Web 2.0 tools and other technologies into lessons can enhance students' academic achievement and increase their motivation towards the subject (Wankel & Blessinger, 2013). These tools facilitate interaction among students, between students and teachers, and with other resources, offering a student-centered approach (Can, 2021). In recent years, it has been observed that teachers have been using Web 2.0 tools more actively and that students' interest in technology and technological applications has increased alongside the use of these tools. The integration of Web 2.0 tools into the learning process not only increases students' engagement with the subject

but also supports conceptual learning processes and enables adaptation to the requirements of the digital age in education (Alp, 2019; Baki, 2022; Conole & Alevizou, 2010; Demirezer, 2022; Ekemen, 2022). An examination of these studies reveals that Web 2.0 tools are effective in making abstract concepts—such as those encountered in science—more concrete, enhancing student motivation, and fostering the development of 21st-century skills (Efe et al., 2022; Gürleroğlu, 2019). It has also been identified that these tools enrich the learning process through gamification, visualization, and interactivity; increase academic achievement; enhance interest in the subject; and promote positive attitudes towards technology (Bolatlı & Korucu, 2018; Gürleroğlu & Yildirim, 2022; Korkut, Mantaş & Yildirim, 2021; Timur et al., 2020). These findings demonstrate that Web 2.0 tools can be effective in teaching processes. “Conduction of Electricity” unit is one of the subjects that students find abstract and challenging to understand, according to studies (Acet & Akyüz, 2020). According to reports, students find it difficult to understand the unit's concepts, which include electrical resistance, conductivity, insulation, the impact of a conductor's type, length, and cross-sectional area on a bulb's brightness, and the structure of the bulb (Günaydın, 2019). Kriek and Gaigher (2006) discovered, in particular, that students struggled to connect the idea of electrical resistance to other events. Additionally, the wealth of research on enhancing students' motivation, academic performance, and attitudes about the "Conduction of Electricity" unit lends credence to this conclusion (Günaydın, 2019; Ivanjek et al., 2021; Kazaklı, 2020; Yildiz et al., 2020). It is therefore considered that developing a guiding material to support teachers in using these tools more effectively and systematically would facilitate their instructional practices, provide guidance in employing them across different subject areas, and positively influence students' conceptual understanding of “Conduction of Electricity” topics. Accordingly, this study aims to develop Web 2.0-supported instructional materials for the “Conduction of Electricity” unit, to examine students' conceptual learning, and to determine their views regarding the process.

Method

The present study utilized an *action research* framework, recognized broadly within qualitative paradigms for its cyclical and reflective nature (Kemmis & McTaggart, 1988; Stringer, 2014). Action research entails a collaborative and iterative process whereby practitioners—such as educators, school leaders, or instructional specialists—and researchers jointly identify and address issues specific to their educational contexts. This approach incorporates successive phases of planning, implementation, observation, and reflection with the dual intention of enhancing practice and producing situated knowledge (Carr & Kemmis, 1986). Within this scope, the study adopted the *technical/scientific/collaborative action research* variant, a subtype designed to rigorously evaluate or pilot interventions framed by established theoretical constructs (Corey, 1953). Under the mentorship of a researcher proficient in the theoretical domain, practitioners introduced an innovative instructional method. Throughout the implementation, the researcher conducted systematic observations and data collection to analyze outcomes, facilitating evidence-based assessments that bridge the divide between conceptual frameworks and practical application. In such studies, there is intensive interaction between the researcher and the practitioner regarding the implementation process. In technical/scientific/collaborative action research, the primary aim of the researcher is to provide a detailed description of this process (Yildirim & Şimşek, 2013). In the present study, the principal researcher sought to comprehensively describe the process by implementing guidance material supported by Web 2.0 tools in the school where they are employed. The steps followed in the action research process are

presented in detail in Table 1.

Table 1. Action Research Process of the Conducted Study

Determination of the Research Problem	The research problem was defined as the development of guidance material supported by Web 2.0 tools focused on the unit ‘Conduction of Electricity’, as well as the investigation of students’ conceptual learning related to this topic.
Formulation of Action Research Questions	Does the use of activities designed with Web 2.0 tools influence students’ conceptual understanding of electricity conduction? What are the students’ perceptions regarding the implementation process of the prepared activities?
Data Collection	Initially, while preparing the activities, an extensive review of the literature was conducted concerning both the topic of electricity conduction and studies related to Web 2.0 tools.
Data Analysis and Interpretation	Following the literature review, the collected data were analyzed and interpreted, thereby forming the theoretical foundation of the study.
Development of the Action/Implementation Plan	At this stage, 26 activities supported by Web 2.0 tools related to conduction of electricity were developed. After a pilot implementation and necessary adjustments, the activities were finalized for the main application. Additionally, five lesson plans for in-class use of the activities were prepared. To evaluate the effectiveness of the study, a Concept Understanding Test and semi-structured interview questions—developed based on expert opinions—were finalized through pilot studies.
Development of the Monitoring Plan	The Concept Understanding Test was administered as a pre-test before the main application and as a post-test following the implementation. Semi-structured interviews were conducted with six students selected based on their high, medium, and low post-test scores, focusing on the process and conceptual understanding. Audio recordings were made during the interviews.
Implementation of the Action Plan and Monitoring	In this phase, a total of 42 sixth-grade students—21 from the pilot study and 21 from the main study—participated in the implementation of the activities prepared with Web 2.0 tools, following the predefined plan.
Analysis and Evaluation of the Implementation	At this stage, the researcher analyzed the results of the implementation, evaluating the effectiveness of the activities and the plan, identifying problems encountered during the process and their causes, and discussing potential measures to address these issues.

Sample

Convenience sampling was employed in this study due to considerations of accessibility and practicality. This non-probability sampling technique enables efficient and timely data collection by selecting participants from cases that are readily available to the researcher within their immediate context. Such an approach is particularly advantageous when alternative sampling strategies are impractical or infeasible (Yildirim & Şimşek, 2013). The

research was conducted through two distinct phases: a pilot study and the main implementation, both carried out at the institution where the principal investigator is employed. One branch of the school was randomly selected to participate in the pilot study, while the other branch was designated as the site for the main implementation. Consequently, the sample comprised 21 sixth-grade students from the main implementation branch of Şehit Erhan Dural Girls Anatolian Imam Hatip High School during the spring semester of the 2023–2024 academic year. In addition, semi-structured interviews were conducted with six students purposively selected from the main study group based on their high, medium, and low scores on the Concept Understanding Test. These interviews aimed to gain deeper insights into the students' conceptual comprehension and their experiences with the learning process facilitated by Web 2.0-supported activities.

Implementation Process

In this study, a teacher's guide material was developed for the 6th-grade Science unit entitled "Conduction of Electricity" grounded in the constructivist learning theory's 5E instructional model and enhanced with Web 2.0 tools. The instructional design comprised a total of 12 class hours, with detailed lesson plans created and executed accordingly. A variety of pedagogical strategies were employed, including direct instruction, question-and-answer sessions, collaborative group work, active learning techniques, classroom discussions, and prediction-observation-explanation sequences. The integration of Web 2.0 technologies facilitated a dynamic and interactive learning environment. The instructional process was structured around diverse activities such as word clouds, concept cartoons, animations, digital presentations, and gamified applications. During the engagement phase, students collaboratively constructed a word cloud using the Wordart application to activate prior knowledge, followed by a guided discussion designed to capture and maintain student attention. In the exploration phase, students participated in prediction-observation-explanation activities supported by worksheets and hands-on experiments. Working in groups, they conducted experiments, documented their observations, and shared findings within the classroom to solidify conceptual understanding. The explanation phase included viewing an animation video sourced from the EBA platform, complemented by detailed scientific explanations delivered through a Canva-supported presentation. To deepen understanding, the elaboration phase featured interactive, game-based learning activities developed via the Wordwall platform. Finally, the evaluation phase involved individual assessments conducted with the aid of Plikers response cards.

Data Collection Instruments and Analysis

In this study, two primary data collection instruments were utilized: a Concept Understanding Test designed to assess the impact of the developed activities on students' conceptual comprehension, and semi-structured interviews aimed at capturing students' perceptions regarding the implementation process.

Concept Understanding Test

The Concept Understanding Test consisted of 15 open-ended questions. The alignment between the test questions and the learning outcomes is presented in Table 2.

Table 2. Learning Outcomes and Corresponding Question Numbers

Learning Outcome	Question Numbers
6.7.1.1. Classifies materials based on their ability to conduct electricity by using a designed electric circuit.	1, 2, 3
6.7.1.2. Explains, with examples, how the electrical conductivity and insulation properties of materials are used in daily life.	4, 5, 6
6.7.2.1. Predicts the variables affecting the brightness of a bulb in an electric circuit and tests these predictions experimentally.	7, 8, 9
6.7.2.2. Defines electrical resistance.	10, 11, 12
6.7.2.3. Recognizes that the filament inside a bulb has resistance.	13, 14, 15

To ensure the validity and reliability of the developed test, feedback was obtained from two science teachers, and a pilot study was conducted. Based on the received feedback, necessary revisions were made, and the final version of the test was prepared.

The students' responses to the Concept Understanding Test were analyzed in two stages. First, each student's answers were categorized and scored according to the categories employed in the study by Abraham, Williamson, and Westbrook (1994) (Table 3). Subsequently, the Wilcoxon signed-rank test was applied to compare students' pre-test and post-test scores, and the results were presented in tabular form. Additionally, frequency tables were generated based on the categorized data according to the learning outcomes derived from the Concept Understanding Test. The total possible score for each student ranged from 0 to 60. Each student's level of understanding was individually evaluated for each question, scored accordingly, and the overall achievement score was computed.

Table 3. Scoring Categories Used in the Concept Understanding Test

Numeric Score	Understanding Category	Description
4	Complete Understanding (CU)	Responses that fully encompass scientifically accepted concepts
3	Partial Understanding (PU)	Responses that include some scientifically accepted concepts
2	Partial Understanding with Specific Misconception (PUMC)	Responses showing partial understanding but containing a specific conceptual misconception
1	Specific Misconception (MC)	Responses that contain conceptual misconceptions
0	No Understanding (NU)	Blank, meaningless, repetitive, irrelevant, or ambiguous responses

Semi-Structured Interviews

Two types of interviews were conducted in this study. Students were asked about their views regarding the implementation process. Interview data collected from six students—selected based on high, medium, and low

scores on the Concept Understanding Test—were analyzed using content analysis, a qualitative data analysis method that involves systematic coding and categorization to identify themes and patterns within textual data (Creswell & Poth, 2018; Elo & Kyngäs, 2008). The findings were organized into tables according to the variables of “theme,” “category,” “code,” “participant, Student1(S1),.....Student N (Sn)” “sample student statements,” and “frequency.” During the analysis, no predetermined coding scheme was employed; instead, natural codes were inductively generated based on students’ expressions, following the conventional content analysis approach (Hsieh & Shannon, 2005).

Findings

Findings Obtained from the Concept Understanding Test

The pre-test and post-test results of the Concept Understanding Test, which was administered to 6th-grade students to examine their conceptual understanding within the “Conduction of Electricity” unit, were analyzed comparatively using the Wilcoxon signed-rank test in SPSS 25.0. The results are presented in Table 4.

Table 4. Wilcoxon Signed-Rank Test Results for Scores Obtained from the Concept Understanding Test

Pre-post test	N	Mean rank	Sum of ranks	Z	p
Negative ranks	0	.00	.00	-4.02	.000*
Positive ranks	21	11.00	231.00		

*p<.05

According to the Wilcoxon signed-rank test, the change in students’ scores on the Concept Understanding Test was statistically significant ($z = -4.02$, $p < .05$). The effect size, calculated based on Cohen’s (1988) criteria, was large ($r = .62$). The median scores increased from the pre-test ($Md = 28.57$) to the post-test ($Md = 49.67$). Finally, this section presents frequency tables and bar charts that show the distribution of students’ responses to the pre- and post-tests of the Concept Understanding Test across categories (CU, PU, PUMC, MC, NU) for each learning outcome.

Table 5 provides the frequency distribution of students’ responses to Questions 1, 2, and 3—aligned with Learning Outcome 6.7.1.1—across these categories.

Table 6. Frequency Distribution of Student Responses to Questions Corresponding to Learning Outcome 6.7.1.1

6.7.1.1 Classifies materials based on their ability to conduct electricity by using a designed electrical circuit.	Question No	Pre- Test					Post- Test				
		CU.	PU.	PUMC.	MC.	NU.	PU.	PU.	PUMC.	MC.	NU.
	1.	5	7	5	0	4	17	3	0	1	0
	2.	7	8	2	0	4	18	2	1	0	0
	3.	12	0	7	0	2	18	0	3	0	0

In the pre-test, the number of students demonstrating Correct Understanding (CU) was 5 for Question 1, 7 for Question 2, and 12 for Question 3. For Question 1, 7 students fell into the Partial Understanding (PU) category, while 5 students were classified under Misconception (PUMC). In Question 2, 8 students were categorized as PU and 2 students as PUMC. Additionally, No Understanding (NU) category, indicating responses devoid of scientific meaning, accounted for 4 students in Questions 1 and 2, and 2 students (9.5%) in Question 3. In the post-test, the number of students classified as CU increased markedly to 17 for Question 1, 18 for Question 2, and 18 for Question 3. The PU category included a total of 3 students across the first two questions, whereas the PUMC category was represented by 3 students in Question 3. Notably, no students fell within these categories for Questions 1 and 2. Moreover, the NU category was not observed in the post-test responses.

Table 6 provides the frequency distribution of students' responses to Questions 4, 5, and 6—aligned with Learning Outcome 6.7.1.2—across these categories.

Table 6. Frequency Distribution of Student Responses to Questions Corresponding to Learning Outcome 6.7.1.2

6.7.1.2 Explains, with examples, how the electrical conductivity and insulation properties of materials are used in daily life.	Question No	Pre- Test					Post- Test				
		CU.	PU.	PUMC.	MC.	NU.	CU.	PU.	PUMC.	MC.	NU.
	4.	9	2	9	0	1	16	0	5	0	0
	5.	6	4	9	0	2	19	0	2	0	0
	6.	20	0	1	0	0	19	2	0	0	0

The percentage of students who showed Complete Understanding (CU) on the pre-test varied from 14% (9 students) to 95% (20 students). Notably, Question 6 exhibited a high level of achievement (95%), whereas only 9 students attained CU in Question 4, and this figure further declined to 6 students for Question 5. Across Questions 4, 5, and 6 in the pre-test, only 3 students (approximately 4.7%) were categorized under No Understanding (NU). Following the intervention, post-test results showed an increase in CU category membership to 16 students for Question 4, 19 students for Question 5, and 19 students for Question 6.

Table 7 presents the frequency distribution of student responses to Questions 7, 8, and 9, which correspond to Learning Outcome 6.7.2.1.

Table 7. Frequency Distribution of Student Responses to Questions Corresponding to Learning Outcome 6.7.2.1

6.7.2.1. Predicts the variables affecting the brightness of a bulb in an electric circuit and tests these predictions experimentally.	Question No	Pre- Test					Post- Test				
		CU.	PU.	PUMC.	MC.	NU.	CU.	PU.	PUMC.	MC.	NU.
	7.	1	3	7	4	5	17	0	3	1	0
	8.	1	3	6	5	6	8	1	12	0	0
	9.	5	6	0	4	6	18	1	0	2	0

For Question 7, only one student (4.8%) was classified in the CU category; the majority of students' responses

were distributed primarily across the PU, PUMC and NU categories, with proportions of 33.3%, 19.0%, and 23.8%, respectively. A similar pattern was observed in Question 8, where the CU rate remained at 4.8%, while the proportion of students in the NU category increased to 28.6%. Although the CU rate for Question 9 increased slightly to 23.8%, the proportion in the NU category remained constant, with a substantial number of students' responses distributed across the MC and PU categories.

In the post-test, the proportion of students classified under the CU category increased to 81% for Question 7 and 85.7% for Question 9. Notably, no students remained in the NU category for these two questions. Although the CU rate for Question 8 rose to 38.1%, 57.1% of the students were still categorized under PUMC. The proportion of students achieving CU prior to the intervention ranged between 4.8% and 23.8%, whereas post-intervention rates increased substantially to 81.0% and 85.7% for Questions 7 and 9, respectively. Meanwhile, the proportion of students in the NU category, which ranged from 23.8% to 28.6% in the pre-test, was completely eliminated in the post-test. It is noteworthy that 12 students remained in the PU category for Question 8.

Table 8 presents the frequency distribution of student responses to Questions 10, 11, and 12, which correspond to Learning Outcome 6.7.2.2.

Table 8. Frequency Distribution of Student Responses to Questions Corresponding to Learning Outcome 6.7.2.2

6.7.2.2.		Pre- Test					Post- Test				
Defines electrical resistance.	Question No	CU.	PU.	PUMC.	MC.	NU.	CU.	PU.	PUMC.	MC.	NU.
		10.	0	1	0	1	19	10	0	4	3
11.	0	4	5	5	6	9	0	6	4	2	
12.	0	0	1	2	18	11	1	6	0	3	

Analysis of the pre-test data revealed that no students (0%) achieved the Complete Understanding (CU) category for Question 10, with only one student (4.8%) classified under Partial Understanding (PU). Additionally, one student (4.8%) was categorized as having MC, while the vast majority, 19 students (90.5%), fell into the No Understanding (NU) category. A similar pattern was observed in Question 11, where no students attained CU, 4 students (19%) were in the PU category, and five students (23.8%) each were classified under Partial Understanding with Specific Misconception (PUMC) and MC categories. Notably, 6 students (28.6%) remained in the NU category. For Question 12, only one student (4.8%) was in the PUMC category, 2 students (9.5%) were in MC, and the majority, 18 students (85.7%), were categorized as NU. In the post-test, the number of students achieving CU for Question 10 increased to 10 (47.6%), while those in the NU category decreased significantly from 19 to 4 students. For Question 11, 9 students (42.9%) reached CU, and 6 students were classified as PUMC, with the NU category reducing to 2 students. In Question 12, 11 students (52.4%) achieved CU, only 3 students (14.3%) remained in the NU category, and 6 students (28.6%) were classified as PUCM.

Table 9 presents the frequency distribution of student responses to Questions 13, 14, and 15, which correspond to Learning Outcome 6.7.2.3.

Table 9. Frequency Distribution of Student Responses to Questions Corresponding to Learning Outcome 6.7.2.3

6.7.2.3. Recognizes that the filament inside a bulb has resistance.	Question No.	Pre- Test					Post- Test				
		CU.	PU.	PUMC.	MC.	NU.	CU.	PU.	PUMC.	MC.	NU.
	13.	2	9	0	1	9	18	3	0	0	0
	14.	0	0	1	7	13	12	0	4	3	2
	15.	8	1	7	0	5	7	2	12	0	0

According to the pre-test results, only 2 students (9.5%) achieved the Complete Understanding (CU) category for Question 13, with the highest proportion, 9 students (42.9%), classified under Partial Understanding (PU). Additionally, 1 student (4.8%) was categorized as MC, and 9 students (42.9%) fell into the No Understanding (NU) category. For Question 14, no students reached the CU category (0%), while 1 student (4.8%) was classified under Partial Understanding with Specific Misconception (PUMC), 7 students (33.3%) under MC, and 13 students (61.9%) under NU. In Question 15, 8 students (38.1%) achieved CU, 1 student (4.8%) was in PU, 7 students (33.3%) in PUMC, and 5 students (23.8%) in NU. In the post-test, the number of students in the CU category for Question 13 increased to 18 (85.7%), with only 3 students (14.3%) remaining in PU. For Question 14, 12 students (57.1%) attained CU, while the remaining students were mostly distributed across PUMC (19.0%), MC (14.3%), and NU (9.5%) categories. For Question 15, the number of students in CU remained at 7 (33.3%), whereas 12 students (57.1%) shifted to the PUMC category.

In order to gain deeper insights into students' perceptions of the instructional process, semi-structured interviews were conducted, and the data obtained from their responses were subjected to a systematic qualitative analysis. This analytical process, consistent with the principles of qualitative research design, involved identifying recurrent themes, categorizing related concepts, and assigning corresponding codes. The resulting framework not only organizes the qualitative findings but also facilitates the interpretation of patterns emerging from the participants' perspectives. The synthesized results are presented in a comprehensive matrix that integrates the dimensions of Theme, Category, Code, Participant, Student Opinion, and Frequency. This matrix, shown in Table 10, serves as a structured representation of how students articulated their experiences and viewpoints regarding the integration of Web 2.0 tools into science education. By aligning these elements, the table enables both the systematic comparison of participant responses and the identification of prevalent trends across the dataset.

Upon examination of Table 10, it is evident that, under the theme of General Attitudes and Perceptions, students expressed that they found the lessons enjoyable, frequently stating that "lessons should always be like this." Regarding the theme of Effects of Web 2.0 Tools on Learning, students indicated that these tools facilitated understanding, promoted permanent learning, and increased their interest in the lesson. One student remarked, "While solving the tests, I recalled the topics we covered in class," highlighting the perceived connection between the lesson content and assessment performance. It was also noted that the tools contributed to improving students' technological literacy. On the other hand, certain challenges were reported, particularly related to time and technical issues, as reflected in comments such as "There was not enough time; we wanted to play the games longer" and "Accessing the internet took our time." Applications such as Canva, Quizizz, Kahoot, and PhET were

well received by the students. Finally, they emphasized that Web 2.0 tools could also be beneficial in other subjects, including Mathematics, Turkish, Social Studies, and English.

Table 10. Theme/Category/Code Matrix for Science Education Supported by Web 2.0 Tools

Theme	Category	Code	Participants	Example Student Statements	Frequency (f)
Science lessons supported by Web 2.0 tools	General attitudes and perceptions	Positive attitude	S1, S2, S4, S11, S15, S18	It was very enjoyable; I wish all lessons were like this.	6
		Negative attitude	–	–	0
Impact of Web 2.0 tools on learning	Contribution to learning	Supports permanent learning	S1, S2, S11, S15, S18	After the lesson, I understood and solved the tests better.	5
		Facilitates understanding	S1, S2, S4, S11, S15, S18	While solving the tests, I remembered the lessons we studied and realized I understood them better.	6
		Increases interest in the lesson	S11, S15, S18, S1	We always wanted to have science lessons.	4
		Provides interactive content	S2, S4, S11, S15, S18	When using Web 2.0 tools, we actively participated by typing answers on the screen. For example, with Quizizz, we took an active role in competitions.	5
		Advantages of Web 2.0 tools	Contribution to the teaching process	Improves digital literacy	S1, S15, S18
Disadvantages of Web 2.0 tools	Challenges and limitations	Time management issues	S1, S2, S11, S15, S18	We wanted to play the games longer, but the lesson ended quickly.	6
		Technical problems / infrastructure deficiencies	S1, S2, S18	Connecting to the internet took our time. We wanted smaller groups, but couldn't due to connection issues.	2
Preferred Web 2.0 tools	Frequently used and liked tools	Quizizz	S15	It was fun to compete with the whole class.	1
		PhET	S11	The simulations caught my	1

Theme	Category	Code	Participants	Example Student Statements	Frequency (f)
				attention. I could build my own circuit as I wished.	
		Canva	S1, S2, S4, S11, S15	It was great to create my own unique designs with Canva.	5
		Kahoot	S18, S4	It is suitable for group work and makes in-class competition exciting.	2
Challenges in using Web 2.0 tools	Problems encountered during use	Technical difficulties (internet, devices, freezing)	S11, S15, S18	There were times when the internet didn't work, and some classmates' computers froze.	3
		Time-consuming nature	S1, S2, S11	The applications were fun, but since we ran out of time, we had to move on to another activity.	3
		Need for prior training on the tools	S15, S18	Our teacher provided training on the tools, but it still took me some time to learn some of them.	2
Use of Web 2.0 tools in other subjects	Expanding application to other lessons	Mathematics	S1, S2, S11, S15, S18	I would understand mathematics better and solve problems faster.	5
		Social Studies	S1, S4	Since Social Studies relies on memorization, I would understand it better.	2
		Turkish	S4, S15, S18	We could develop our vocabulary with word clouds and create our own designs.	3
		English	S1, S18	Learning vocabulary would be easier, and all lessons would become more enjoyable.	2

Discussion and Conclusion

This study employed a conceptual understanding test to investigate the impact of Web 2.0-enhanced instructional materials on students' conceptual learning. Analysis of the pre-post test results, supported by the Wilcoxon signed-rank test findings (see Table 4), revealed a statistically significant improvement in students' post-test scores compared to their pre-test scores ($z = -4.02, p < .05$), indicating a positive effect of the intervention. These

results align with previous studies (Baki, 2022; Gürleroğlu & Yildirim, 2022; Köse et al., 2021) reporting that Web 2.0 tools foster conceptual understanding, academic achievement, and positive attitudes toward technology.

The observed increase in students' ability to provide higher-order responses underscores the value of integrating cognitive and visual supports into instruction. In this respect, the Web 2.0 tools utilized in the present study appear to have made a notable contribution. Consistent with this, prior research has demonstrated the effectiveness of Web 2.0-based approaches in promoting conceptual development. For example, Can (2021) found that conceptual cartoons supported by Web 2.0 tools enhanced students' science achievement and attitudes, while Alp (2019) reported significant gains in conceptual understanding following a Web 2.0-supported Scratch-based learning process. These findings corroborate the marked increase in "Complete Understanding" levels observed in the current study. Moreover, Demirezer (2022) reported that Web 2.0-supported activities positively influenced conceptual achievement alongside visual literacy and spatial skills. Collectively, these results provide robust evidence that Web 2.0 tools can substantially enhance conceptual learning outcomes.

Analysis of students' responses to the conceptual understanding test, based on the learning outcome 6.7.1.1 ("Classifies materials according to their ability to conduct electricity using an electric circuit they have designed"), revealed notable improvements in understanding the concepts of electrical conductivity and insulation. In the pre-test, the proportion of students in the "No Understanding" (NU.) category for Questions 1, 2, and 3 was 19%, 19%, and 9.5%, respectively; these rates were entirely eliminated in the post-test. Concurrently, the "Full Understanding" rates rose to 81%, 85.7%, and 85.7% for the same questions (see Table 5). Conductivity and insulation are among the challenging concepts in science education, often remaining at an abstract, rote-learning level due to their limited observability in daily life. Previous research (Alp, 2019; Yildirim, 2020) has demonstrated that the visual and interactive affordances of Web 2.0 tools can effectively address such abstract-concept misconceptions. In the present study, the guide material—particularly through the integration of PhET simulations—enabled students to virtually test and observe conductive and insulating materials within an electric circuit, promoting experiential and comparative learning. Complementary tools such as Quizizz supported knowledge reinforcement, while Canva-facilitated concept mapping helped structure conceptual knowledge. These findings align with prior studies (Baki, 2022; Cıtaç, 2023; Köse et al., 2021) showing that Web 2.0-supported instruction enhances both achievement and attitudes toward technology, with Köse et al. (2021) further emphasizing its positive impact on conceptual understanding. Accordingly, the guide material's combination of visual, auditory, and experiential learning opportunities appears to have contributed significantly to students' improved comprehension of conductivity and insulation.

The learning outcome 6.7.1.2 ("Explains, with examples, the purposes for which the conductive and insulating properties of materials are used in daily life") aimed to assess not only students' recognition of these properties but also their ability to relate them to real-life contexts. Pre-test data indicated a low level of such contextual association: for Questions 4 and 5, the CU category rates were 43% and 29%, respectively, while for Question 6 this rate reached 95%. Following the intervention, the CU. rates for Questions 4, 5, and 6 increased to 76%, 90%, and 90%, respectively (see Table 6). This improvement is attributed to the use of interactive competition environments and visual content creation tools such as Quizizz and Canva, which enabled students to learn in an

enjoyable yet meaningful way. Indeed, student statements such as “I designed my own electrical device using Canva and understood the function of each part” (see Table 10) directly reflect this outcome. Similar findings have been reported in the literature. For example, Gürleroğlu and Yildirim (2022) demonstrated that students were more successful in transferring concepts to concrete contexts when working with Web 2.0–supported content, while Demirezer (2022) noted that these tools facilitate conceptual transfer through the enhancement of visual literacy skills.

The learning outcome 6.7.2.1 (“Predicts the variables affecting the brightness of a bulb in an electric circuit and tests these predictions through experimentation”) aimed to foster students’ understanding of the variables influencing bulb brightness and their ability to experimentally explore the relationships among these variables. Pre-test results revealed low levels of conceptual understanding: for Questions 7 and 8, the “Complete Understanding (CU)” rate was only 4.8%, and for Question 9, 23.8%. These low rates suggest that students struggled to distinguish variables such as resistance, current, and voltage, and to conceptualize their causal relationships. By the end of the intervention, post-test results showed substantial improvement: CU. rates for Questions 7 and 9 increased to 81% and 85.7%, respectively, indicating that Web 2.0 tools had a positive effect on learning by enabling visualization and experiential exploration of complex relationships (see Table 7). In particular, the use of PhET simulations allowed students to manipulate variables independently and observe the resulting effects. As one student noted, “I didn’t understand why the bulb’s brightness was changing, but when I set up the circuit, I realized” (Table 14), clearly reflecting the power of experiential learning. However, the fact that 57.1% of students remained at the “Partial Understanding with Misconception” (PUMC.) level for Question 8 indicates that some still confused resistance and voltage. This finding aligns with Demirezer’s (2022) observation that certain concepts require more extensive experimental practice and repetition. Similarly, Yildirim (2020) reported that Web 2.0–supported instruction enhances students’ self-directed learning with technology, which in turn supports the internalization of complex concepts. Alp (2019) emphasized that Scratch-based Web 2.0 applications improve conceptual understanding and critical thinking, particularly by concretizing abstract concepts through digital interactive tools. Likewise, Gürleroğlu (2019) found that learning environments in which students take active roles in experimental processes significantly improve their ability to grasp causal relationships—a finding consistent with the improvements observed in this study.

The learning outcome 6.7.2.2 (“Defines electrical resistance”) aimed to measure students’ understanding of the concept of electrical resistance. Pre-test results revealed that no students achieved “Complete Understanding” (CU.) in Questions 10, 11, or 12. In particular, 85.7% of students were in the “No Understanding” (NU.) category for Questions 10 and 12, while 28.6% fell into this category for Question 11, with the remainder distributed across the “Partial Understanding” categories (PU, PUMC, MC). These findings indicate that the concept of resistance was abstract and cognitively challenging for students. Post-test results, however, showed a marked improvement: CU. rates rose to 47.6% for Question 10, 42.9% for Question 11, and 52.4% for Question 12 (see Table 8). This progress can largely be attributed to the PhET simulations used in the guide material, which allowed students to manipulate resistance values in a circuit and directly observe the effects. This experiential approach helped them conceptualize resistance more meaningfully. As one student expressed, “Resistance is like an obstacle in the circuit; it slows down the current. I saw it that way in PhET” (see Table 10), clearly illustrating the contribution

of these tools to conceptual understanding. Similar findings are reported in the literature. Ekemen (2022) emphasized that Web 2.0–supported science instruction enhances digital literacy and critical thinking skills while fostering conceptual awareness. Likewise, Sarıkaya and Aydın (2021) found that EBA- and experiment-supported activities significantly improved achievement in topics related to electric circuits, demonstrating that supporting abstract concepts with concrete experiences strengthens learning.

The learning outcome 6.7.2.3 (“Recognizes that the filament inside a bulb has resistance”) aimed to assess students’ awareness of the resistance exhibited by a bulb’s filament and their ability to apply this knowledge in a functional context. Pre-test results showed that the proportion of students achieving “Complete Understanding” (CU.) was as low as 9.5% for Question 13 and 0% for Question 14, with 61.9% in the “No Understanding” (NU.) category for Question 14 (see Table 9). In the post-test, however, CU. rates rose markedly to 85.7% for Question 13 and 57.1% for Question 14, indicating that students had moved beyond merely recognizing the concept to understanding it in a functional context. Nonetheless, the fact that 57.1% of students remained in the “Partial Understanding with Misconception” (PUMC.) category for Question 15 suggests that, for some, the concept was only partially internalized. This may be attributed to the multifaceted nature of electrical resistance, which can be challenging to fully conceptualize, as well as to individual differences in learning pace and ability to process abstract concepts. The observed improvement can be largely attributed to the PhET simulations incorporated into the guide material, which enabled students to learn through direct experimentation. Additionally, tools such as Canva helped students visualize and articulate the concept, while game-based platforms like Quizizz reinforced their understanding. As one student reflected, “I used to wonder why the bulb was dim, but in the PhET circuit, I realized the filament has resistance” (see Table 10), clearly illustrating the impact of experiential learning. These findings are consistent with the literature. Gürleroğlu (2019) emphasized the importance of experimental contexts in concretizing abstract concepts related to resistance. Bolatlı and Korucu (2018) highlighted that learning environments supported by interactive simulations enhance students’ abilities to question scientific concepts and establish causal relationships. Similarly, Sarıkaya and Aydın (2021) reported that constructivist, experiment-based activities significantly improve achievement in topics related to electric circuits.

Overall, a significant progression was observed across all learning outcomes, with students moving from the “No Understanding” level toward “Complete Understanding.” It can be concluded that interactive, student-centered instructional practices supported by Web 2.0 tools effectively enhance conceptual understanding. However, the persistence of misconceptions in certain outcomes indicates the need for ongoing revision of this instructional model and the restructuring of content according to conceptual difficulties.

An analysis of students’ perspectives regarding the science course supported by Web 2.0 tools revealed that their responses clustered into eight principal themes (see Table 10): general attitudes and perceptions, contributions to learning, contributions to the instructional process, disadvantages, preferred tools, challenges encountered during usage, and application in other subject areas. Examination of Table 10 indicates that students’ overall experiences with the intervention were predominantly positive. Within the theme of “General Attitudes and Perceptions,” all participants reported that Web 2.0–enhanced lessons were engaging and enjoyable, characterizing this instructional approach as more motivating and captivating relative to traditional pedagogy (Participants S1, S2,

S4, S11, S15, S18). The statement, “The lessons were very enjoyable; I wish all classes were conducted in this manner,” (see Table 10) succinctly encapsulates the prevailing student sentiment. These findings suggest that the inherently interactive and learner-centered attributes of Web 2.0 technologies substantially augment learners’ engagement and interest in the educational process. Corroborating these findings, Yazıcıoğlu et al. (2023) observed that instruction incorporating Web 2.0 tools was perceived by students as enjoyable, memorable, and comprehensible, thereby fostering enhanced motivation and interest. Moreover, Akbaba (2019) demonstrated that Web 2.0–supported science instruction favorably influenced students’ attitudes toward the subject matter as well as their dispositions toward technology use. Collectively, these outcomes imply that the positive student perceptions are largely attributable to the interactive, participatory nature of the Web 2.0 tools employed.

Under the theme of “Contribution to Learning,” students reported that Web 2.0 tools supported conceptual understanding, enhanced the retention of knowledge, and facilitated comprehension. For instance, statements such as “After the lessons, I better understood and solved the tests” and “While solving tests, I recalled the lessons we covered” reflect students’ learning experiences. These findings indicate that Web 2.0 tools contribute positively to students’ cognitive processes, supporting durable learning. Similarly, Can (2021) reported that Web 2.0–supported conceptual cartoons positively impacted students’ achievement and conceptual understanding in science courses. Additionally, Yildirim and Şimşek (2023) noted that interactive digital content enhances students’ meaning-making processes.

One of the most salient aspects highlighted regarding the contributions of Web 2.0 tools to the instructional process is the enhancement of students’ digital competencies. Student testimonies, such as “I acquired proficiency in tools like WordArt and Canva, and now independently create my own designs,” (see Table 10) indicate not only an advancement in disciplinary knowledge but also a significant development in digital literacy skills. This outcome underscores the interdisciplinary skill-building potential inherent in Web 2.0–supported pedagogies. This assertion is corroborated by Yazıcıoğlu et al. (2023), whose findings reveal that students exhibited growth not only in academic knowledge but also in creative production and digital proficiency through engagement with Web 2.0 tools. Similarly, Sarıkaya and Aydın (2021) observed that such implementations contribute substantively to the cultivation of multifaceted competencies.

Conversely, participants identified several constraints associated with the use of Web 2.0 tools. Challenges related to “time management” and “inadequate technical infrastructure” emerged as significant impediments impacting the efficacy of instructional delivery. Illustrative student comments such as “We wished to engage with the games more extensively; however, the lesson duration was insufficient,” and “The time consumed in establishing an internet connection detracted from instructional time,” exemplify the detrimental influence of technical and temporal limitations on the learning experience. Moreover, a subset of students emphasized the necessity of preliminary training regarding the utilized tools, highlighting that effective technology integration extends beyond mere provision of resources to encompass comprehensive pedagogical guidance and technical support. These observations align with prior research; Uysal (2020) emphasized that factors such as time allocation, internet connectivity issues, and hardware inadequacies can adversely affect the effective deployment of Web 2.0 technologies within classroom environments. Correspondingly, Ekemen (2022) noted that preparatory training for

students significantly enhances the overall efficacy of technology-assisted learning interventions.

Another notable finding presented in Table 10 is students' explicit preferences for specific Web 2.0 tools. Platforms such as Canva, Quizizz, PhET, and Kahoot emerged prominently, with Canva's design-oriented interface and the competitive, interactive nature of Quizizz and Kahoot receiving particular acclaim. These tools not only facilitate content delivery but also actively engage students in the learning process. Expressions such as "Competing with the class was enjoyable" and "I can build my own circuit as I wish" illustrate how this interactivity directly contributes to learning. Ortakarsu and Sülün (2022) emphasized that students exhibit higher motivation and participation in competition-based learning environments. Additionally, Can (2021) reported that production-based tools like Canva enhance students' creativity and engagement with the lesson.

Furthermore, students articulated the view that Web 2.0 tools should be integrated into other subject areas as well. They suggested that these tools could be effectively utilized in mathematics, Turkish language, social studies, and English courses, contributing to making lessons more enjoyable. These perspectives underscore the flexibility and efficacy of Web 2.0 tools as integrative resources applicable across disciplines, not limited to science education alone. Correspondingly, Yazıcıoğlu et al. (2023) and Sarıkaya and Aydın (2021) highlighted the high interdisciplinary potential of Web 2.0 tools and their positive impact on achievement in various subject areas.

In summary, the student perspectives presented in Table 10 indicate that Web 2.0 tools contribute positively not only to academic achievement but also to students' attitudes toward learning, classroom engagement, digital competencies, and interdisciplinary skills. However, technical challenges, time constraints, and the need for preliminary training must also be considered. Accordingly, the planning of such innovative instructional models should incorporate appropriate infrastructure and time management strategies to ensure effective implementation.

Recommendations

Within the scope of the present study, the quantitative and qualitative findings indicate that science education facilitated through Web 2.0 tools exerts a positive impact, particularly on students' conceptual understanding. Nevertheless, the study is constrained by its limited sample size and the examination of a single unit within the science curriculum. Accordingly, the generalizability of the findings could be enhanced by extending the research to encompass students from diverse socioeconomic backgrounds, different geographic regions, and varying age groups, thereby enabling a comparative analysis of the efficacy of Web 2.0 tools.

The Web 2.0 tools used in the guide material for the study are limited Canva, Quizizz, Kahoot, WordArt, and PhET. The investigation revealed that platforms such as Canva, Quizizz, Kahoot, WordArt, and PhET contribute effectively to the development of students' meaning-making, reinforcement, and application skills. These digital tools and the others can be systematically integrated into science education curricula through a constructivist pedagogical framework.

According to student perspectives, significant challenges associated with the implementation of Web 2.0 tools include time limitations and technical malfunctions. To mitigate these issues, it is recommended that example

lesson plans designed to optimize instructional time be developed and disseminated among educators, alongside initiatives aimed at addressing infrastructural deficiencies within educational institutions.

Furthermore, interviews with students highlighted a preference for the utilization of Web 2.0 tools beyond the confines of science instruction, extending to disciplines such as Turkish language, mathematics, English, and social studies. Restricting the deployment of these tools solely to science education may limit their pedagogical potential; therefore, their active application across multiple subject areas is likely to enhance the durability of learning outcomes. In this regard, fostering the interdisciplinary use of Web 2.0 tools is advisable.

Notes

This study was taken from the first author's master thesis conducted under the supervision of the second author.

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