

Enriching Elementary Science Lessons with Digital Tools: An Action Research Study*

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ABSTRACT

This action research study explores how digital tools can enrich elementary school science lessons, with particular attention to student voices in shaping the learning experience. Conducted over a 3-week period in a private international elementary school, the study integrated videos, animations, 2D and 3D simulations, and gamified applications across different instructional phases. Multiple data sources - including teacher reflection journals, observation protocols, student questionnaires, focus group interviews, and validity committee records, were analyzed through thematic analysis. Students' voices highlighted that digital tools made science learning more enjoyable, increased their engagement, and supported their understanding of scientific concepts. Classroom observations, however, indicated challenges such as limited instructional time, technology-related distractions, and the risk of overusing certain tools. To address these issues, the teacher implemented strategies such as aligning tools with specific learning objectives, creating structured integration plans, and selecting cognitively demanding tasks. By combining students' voices with authentic classroom observations, this study contributes to the literature on digital tool use in science education and offers practical implications for teachers and policymakers aiming to make elementary science lessons more engaging and meaningful.

KEYWORDS: Classroom practices, digital tools, elementary school, practitioner's action research, Science education

INTRODUCTION

The integration of technology into 21st-century classrooms has been widely promoted for its potential to enhance student learning. In science education, numerous studies highlight benefits such as fostering critical thinking, problem-solving, deeper conceptual understanding, and greater engagement (Arora and Chander, 2020; Darwin et al., 2023; Kim et al., 2007; Mishra, 2017; Yilmaz, 2023). Such approaches also cultivate curiosity and sustained interest in science learning (Kermani and Aldemir, 2015; NSTA, 2014; 2016). The integration of digital technologies into middle school science instruction can also significantly increase student motivation (Omari et al., 2024).

At the same time, research shows that effective use of technology in classrooms is often hindered by issues such as limited pedagogical and technical expertise, low teacher self-efficacy, and difficulties in aligning digital tools with curricular goals (Dawson, 2008; Sorensen et al., 2007; Valanides and Angeli, 2008; Varma et al., 2008). These findings underscore that successful technology integration hinges not solely on access to tools or their technical operation, but more critically on the pedagogical rationale and strategic methods through which they are employed to support student learning (Stoilescu, 2015). Scholars such as Kuo (2015), Wang et al. (2011), and Ünlü and Dökme (2015) similarly argue that the

core issue in science education is not the availability of digital tools, but rather the effectiveness of their integration into teaching practices. Recent studies have highlighted that even after the pandemic; teachers will still face pedagogical and infrastructural barriers (Espinosa et al., 2025; Phuong, 2025).

Ensuring that all students gain the knowledge and confidence in science necessary to be informed citizens in a society that is becoming more scientific and technologically advanced is a major objective of science curriculum worldwide (Hodson and Wong, 2017). Recognizing the pivotal role of science education in equipping individuals to confront, adapt to, and resolve future challenges, it is imperative for educators to investigate and adopt effective strategies for integrating digital technologies into science education. In this context, digital tools – ranging from videos and animations to simulations and gamified applications – are resources that are both widely accessible and readily applicable in science classroom settings. Kabataş-Memiş et al. (2023) reported that when pre-service teachers were encouraged to integrate digital technologies into their course plans, they predominantly opted for readily accessible tools such as videos, simulations, animations, and game-based applications like Kahoot. However, despite the availability of such technologies and studies on the use of these in pre-service teacher training, there remains a need for more classroom-based studies that examine how science teachers

apply these tools in real teaching contexts and how students experience them. Bolaños, Salinas, and Pilerot (2023) observe that studies that document authentic classroom practices still remain limited. Practitioner action research offers a valuable approach for teachers to explore and critically reflect on how such tools can be meaningfully integrated (Briscoe and Wells, 2002). It has also been recognized as an effective framework for investigating instructional strategies that enhance both teaching and learning (Kuo, 2015; Wang et al., 2011).

Many studies have examined the integration of technology into science education; however, most have relied on various research methods that paid limited attention to authentic classroom practices. In particular, the strategies adopted by teachers to integrate readily available digital tools and students' perspectives on how these tools shape their learning remain underexplored. Addressing this gap, the present study investigates how a science teacher in a private international elementary school employed digital tools – specifically videos, animations, 2D and 3D simulations, Kahoot, and Wordwall – over 3 weeks of lessons, foregrounding both classroom realities and student voices. Specifically, it investigates:

1. Which tools were used at different lesson phases to support science learning?
2. How students perceived the digital-tool-supported activities; and
3. What challenges emerged during implementation, and how did the teacher address them?

METHODOLOGY

Research Design

Practitioners' action research in order to improve teaching practices while also allowing the teacher-researcher to grow as a reflective practitioner and provide new information about their students is conducted (Ballenger, 2009; Gay, Mills, and Airasian, 2012). Within the framework of this study, the Stringer (2014) action research model was employed. According to Stringer (2014), the fundamental action research procedures are summed up in a straightforward “look-think-act” pattern. In the “look” phase, researchers collect data to identify problems in the implementation process. In the “think” phase, this data is analyzed, and problems are identified; these problems are prioritized, and action plans are created to solve them. In the “act” phase, these actions are implemented, and the implementation process is linked to the “look” phase, creating a cyclical process.

Pilot Study

Before the main implementation of the study, a pilot study was conducted with a group of elementary school students. During the pilot study, the students participated in a science lesson focused on the topic of paper chromatography. Various technological tools, such as an instructional video sourced from YouTube, a simulation from Amrita OLABs, and Wordwall, were used. Following the lesson, data were collected from the students using observation protocols and focus group

interviews. These data collection instruments were reviewed based on the four expert opinions. The results of the pilot study helped the science teacher revise and develop his science lesson plans for the action research implementation process.

Action Research Implementation Process

The action research process began with the formation of a validity committee consisting of two faculty members, a subject matter expert who is also a science teacher at the same school where the study was carried out, and the science teacher who practiced the technology integration. Three of the four committee members have PhD degrees. The committee reviewed the lesson plans and scrutinized the technological tools for integration. After each week's implementation, the collected data were analyzed by the committee, which then devised and implemented action plans as lesson plans for the subsequent lessons.

Research setting

This study was conducted at a private K-12 school in Ankara, Türkiye, which caters to a diverse student body from 47 different countries and follows both the Turkish national curriculum and the International Baccalaureate (IB) programme. The school was chosen as the research setting primarily because the practitioner action researcher was working at the same school as a science teacher. Before the instruction of science lessons integrated with various technological tools, the classroom seating was rearranged from traditional rows into two groups of four desks each, creating a cooperative seating arrangement. In addition, each pair group had a laptop set up in front of them for use during the lesson, and a smartboard and whiteboard were also available for use throughout the lesson. Throughout the implementation, the students were grouped, provided with the necessary technological tools, and engaged in collaborative work. During the implementation, Unit 3, Forces and Energy, serves as the focus of the study. This unit was implemented over 3 weeks, covering Forces and Motion, Speed, and Describing Movement in consecutive weeks. The implementation process continued until all identified problems were addressed and resolved. Therefore, each week the action research cycle of Stringer, look-think-act, was realized

Participants

Eight 7th-grade students, ranging in age from 13 to 14 years were participated in the study. The reason for this small number of participants is that the small group constitutes the population of the classroom.

Data Collection and Analysis

Data of the study were collected from validity committee members, the practitioner-researcher, and the participating students through various data collection tools. These three sources of data had equal value on the action decisions of each week's implementation.

Data collected from validity committee meetings

The validity committee conducted four meetings, and the average duration of the four meetings was 108 min.

Data collected from the practitioner science teacher

The researcher, who is the practitioner science teacher, wrote reflective journals before and after each implementation week, resulting in a total of six journals. This study also employed the participant-as-observer (Merriam and Tisdell, 2016) technique, where the researcher both taught the science lesson with integrated technology and simultaneously observed student interactions and behaviors within the instructional setting. An observation protocol was used to systematically record behaviors and events. During the lesson, brief notes were taken on the observation protocol, which were then expanded into detailed notes, including reflections on the physical setting and the observer's thoughts. Each week, immediately following the implementation, the researcher wrote detailed observation field notes without a fixed format, documenting aspects such as seating arrangements, classroom activities, and student interactions with technology, challenges encountered, and students' behavior. The lesson plans, taken in this study as action plans, created before the implementation by the science teacher under the supervision of the validity committee, were detailing the integration of technology into science lessons. Three distinct 80-min lesson plans were developed for the 3 weeks.

Data collected from the participating students

The students used exit tickets in the form of reflections to share their perspectives during the implementation, producing a total of eighteen exit tickets over 3 weeks. These tickets, submitted at the end of each lesson, addressed the technological tools used, their impact on comprehension and engagement, challenges faced, and overall thoughts on integrating technology into science lessons. In addition to exit tickets of the science course, the participants' views were collected also through semi-structured focus group interviews after each implementation week to gather their perspectives on the technology-integrated science lessons. A total of three focus group interviews were held, one each week following the lessons, using digital audio recorders to ensure accurate documentation. A questionnaire, designed to gather specific data from students about the science lesson integrated with technology, was also utilized in this study. The questionnaire included a rating scale for the students to assess their understanding, problems encountered, and enjoyment of the lesson, along with space for written feedback. This led to the creation of a questionnaire with three main questions addressing these aspects, allowing students to rate each on a scale of 1–10 and provide additional comments without indicating their names on the forms. After each week's science course, the students filled in the questionnaires.

Data analysis

This study gathered mostly qualitative data and a questionnaire. Thematic analysis was conducted based on the research questions, and these were interpreted alongside the small amount of quantitative findings. Thematic analysis systematically organizes and analyzes complex datasets to identify overarching themes, involving careful reading and

re-reading of the transcribed data to uncover and categorize these themes (Dawadi, 2020; King, 2004).

Validity and Reliability

In this study, a validity committee was integral in addressing the issues, holding regular meetings to evaluate technological tools, review lesson plans and weekly data, conduct macro-level analysis, and develop solutions to challenges and prepare action plans. They also aided in refining data collection instruments. The pilot study also contributed to the validity. In addition, time, researcher, and data triangulations were employed to enhance validity. Data were collected from diverse sources. The data collection spanned all stages of the study – pre-implementation, during implementation, and post-implementation – over a 3-week period. In addition, the researchers in the validity committee analyzed the collected data throughout the implementation, took part in action decisions, which further contributed to triangulation by involving them in identifying and resolving emerging issues. An inter-coder reliability study was conducted with a validity committee member. The committee member was given 30% of the data without knowledge of the themes developed by the researchers. The analysis results were compared, and the researchers met to arrive consensus on the thematic set, and the whole theme set was revised accordingly.

Quality in this action research was addressed through the criteria proposed by Herr and Anderson (2005), specific to action research. Outcome validity was ensured by achieving successful results through weekly macro analyses and validation by the committee (Gall, Gall, & Borg, 2003). Process validity was maintained through systematic data collection, triangulation, and strong participant interaction, with ongoing monitoring by the validity committee (Hendricks, 2006). Democratic validity was achieved by obtaining informed consent and including student perspectives and committee feedback. Catalytic validity was supported by using reflection journals and exit tickets. Dialogic validity was ensured through continuous engagement with the validity committee, which reviewed and provided feedback on all research stages, and respecting participants' students' perspectives through focus group interviews, exit tickets, and questionnaires.

Ethical Considerations

Since this study involved participants under the age of 18, in addition to official permission from the Ministry of National Education, verbal consent was first obtained from the participating children, school administration, and parents, followed by written informed consent. Students and parents were informed that participation in this study was voluntary and that the research process and expectations of the students during the study were explained. It is stated in the informed consent that the identities of the students will be kept completely confidential in scientific publications (theses, articles) to be produced, and that no details revealing their identities will be included in the publications. All students and parents approved voluntary participation. Ethical approval

was sought and obtained from the Turkish State University. Official permission was also secured from the Ministry of National Education.

RESULTS

Results on the Digital Technologies that were used to Improve Students' Understanding

During the 3-week implementation process, various technological tools were integrated to enhance the students' understanding of scientific concepts. Table 1 below highlights the technological tools integrated throughout the 3-week implementation.

Each 80-min lesson was structured into three main phases – introduction, development, and conclusion – during which different technological tools were employed for distinct instructional purposes, as outlined in Table 1. In the introduction phase, videos and animations were utilized to lay the conceptual foundation, present simulation tasks, and engage the students. During the development phase, hands-on activities supported by 2D and 3D simulations were implemented to deepen and solidify the students' understanding. In the conclusion phase, interactive and enjoyable activities were employed to assess the students' comprehension effectively through game-like Web 2.0 tools such as Wordwall, ESL Games Plus, and Kahoot.

Results on the Students' Views on Digital-Tool-Supported Science Learning Activities

Throughout the 3-week implementation of science lessons integrated with various technological tools, students expressed a range of views, insights, and preferences regarding the use of technology in their lessons. These perspectives were collected through focus-group interviews, exit tickets, and open-ended questionnaire responses at the end of each lesson. The main themes were derived from the students' views on the use of technological tools in their learning activities: Enjoyment of interactive elements and emotional responses, enhanced comprehension and performance, and the demand for continuous use of technology in lessons.

Under the “enjoyment of interactive elements and emotional responses” theme, the students described how the integrated technological tools enhanced their enjoyment of the science lessons. The use of these interactive tools heightened their stimulation and interest, leading to increased active participation and sustained focus during the lessons. They

described the lesson as fun, interesting, enjoyable, highlighting how it enhanced their focus and visualization. According to the students, the lessons made them feel happier, more comfortable, focused, better, energetic, and great. The examples from the students' views are the following: “It contained fun simulations that were easy to understand and enjoyable” (Student 2 - 1st week's Questionnaire). “Today's science lesson was extremely fun because we learned by using technology, which helps you learn better. Moreover, we watched an animation and played Kahoot, which made it more amazing” (Student 8 - 1st week's Exit Ticket). “It made the lesson more fun and interesting, and it made everything easier to understand because I could see it and how it was done” (Student 1–3rd week's Focus Group Interview). “So, I felt better. Yeah, it was more interesting and enjoyable than it usually is, and a lot more” (Student 3–2nd week's Focus Group Interview).

According to the ratings the students provided in the questionnaire, all the students gave 9 and 10, indicating an enhancement in their overall enjoyment of the lesson due to the integration of technological tools.

“Enhanced Comprehension and Performance” theme underscores the role of integrated technological tools in enhancing the students' comprehension and performance. According to the students' views, the tools enabled them to better grasp scientific concepts and visualize complex ideas. The examples from the views of the students are: “I understand well with technology. It helped me to understand how to calculate speed and how to calculate distance and time during simulation” (Student 7–2nd week's Questionnaire). “I think it helped me to understand how the graphs work better and how we can, um, understand the line, the speed, and the distance, and I think it was very clear” (Student 2–3rd week's Focus Group Interview). “Today's lesson was really fun because we used interactive video, 3D simulation, and Kahoot. I enjoyed and understood the lesson because of these technologies.” (Student 4–3rd week's Exit Ticket).

The ratings the students provided in the questionnaire completed during implementation, reflecting how the integrated technological tools contributed to enhancing their understanding of the science lesson. Students provided ratings of 9 and 10 out of 10. This indicates that these students strongly believe that the technological tools integrated into the science lesson had a substantial impact on their understanding of the scientific concepts taught.

Table 1: Technological tools and reasons for integration across lesson phases

Week of Implementation	Beginning of the lesson: Lay the foundation, demonstrate simulation tasks, and engage students	Middle of the lesson: Hands-on activities and solidify understanding	End of the lesson: Assess understanding in an interactive and enjoyable way
1 st week	<ul style="list-style-type: none"> • Video • Animation 	<ul style="list-style-type: none"> • Simulation (PhET) • Simulation (Olabs) 	<ul style="list-style-type: none"> • Wordwall • Kahoot
2 nd week	<ul style="list-style-type: none"> • Video • Animation 	<ul style="list-style-type: none"> • Simulation (PhET) 	<ul style="list-style-type: none"> • Kahoot • ESL Games Plus
3 rd week	<ul style="list-style-type: none"> • Interactive video 	<ul style="list-style-type: none"> • 3D Simulation (CoSpacesEdu) 	<ul style="list-style-type: none"> • Kahoot

“The demand for continuous use of technology in lessons” theme emphasizes the students’ demand for the continued integration of technological tools in their science learning experiences. They expressed a desire to maintain the use of these tools due to their benefits, such as increased engagement, enjoyment, and improved understanding. Some examples of their views are as follows: “I think we should keep using it because it’s more interesting and helps us learn better. They should stay. And we should keep using the technological tools, especially simulations from PhET and Kahoot” (Student 6–2nd week’s Focus Group Interview). “I liked the 3D simulation. I hope we should do it every day” (Student 4–3rd week’s Exit Ticket).

Results on the Problems Encountered in the Process of Integrating Technology into Science Lessons and their Solution

The integration of technology into science lessons encountered some challenges, prompting strategic decisions to ensure their seamless integration. These problems were presented to the validity committee members during meetings, and the committee also confirmed the presented problems by examining the data set. The problems encountered during the 3-week implementation and how they were resolved are given below:

- Techno-centric distractions
- Time constraints
- Excessive technology integration
- Preference for computer peripheral functionality
- Difficulty in assessing individual students’ understanding.

The issue of “techno-centric distraction” became apparent when the students became overly engrossed in the technological tools integrated into the lesson, especially the simulations. During the lesson, the students were assigned simulation tasks, which they completed quickly and engaged in unrelated activities. One group got caught up in a different simulation task, while a student from another group opened a new browser window on the laptop intended for the simulation task and began surfing the internet. This behavior led to distractions, diverting their attention away from the lesson. The researcher detailed these challenges in the observation field notes as follows:

“The issue of techno-centric disruptions surfaced as students became overly engrossed in the technological tools, particularly the simulations, diverting their attention away from the teacher and the core lesson content. Even after the designated task, some students continued to engage in unrelated activities on their laptops, detracting from the ongoing lesson.” (20th November, 2023, Observation Field Note, Line Number: 90–93).

The issue of techno-centric distractions was presented to the validity committee members, and a validity committee member suggested that perhaps the simulation tasks given to the students were too easy, leading them to complete the tasks quickly and engage in unrelated activities, and suggested giving the students more challenging tasks. Other members

of the committee accepted the recommendation, and it was implemented in the subsequent implementation, and the issue of techno-centric distraction was not observed again.

“Time constraints” problem encountered by the researcher was time constraints, primarily arising from challenges in managing time due to the integration of technological tools into the lesson. In the observation field note recorded by the researcher at the end of the first implementation, the researcher elaborated on how the arrangement of the classroom to accommodate the technological tools for the science lesson took a significant amount of time from the lesson. This is what the researcher recorded in that regard:

“The issue of time posed a notable challenge. It took nearly 20 min to arrange the seating, set up the students’ laptops, and open and log into the various technological tools, including the Cambridge Lower Secondary Science Stage 8 software.” (20th November, 2023, Observation Field Note, Line Number: 80–83).

This issue of time constraints was presented to the validity committee members and the following suggestion was implemented next week: “To address the time problem, review the entire lesson plan and calculate how many minutes each stage will take on average” (Validity Committee Meeting No. 2). The technology integration timeline developed for the subsequent lessons outlined the steps, activities, time allocations, and duration of the entire lesson, providing a structured guide to be followed.

“Excessive technology integration” was also encountered. For context, in the first implementation, six technological tools, namely: a video, an animation, simulations from OLABS and PhET, Wordwall, and Kahoot, were integrated. The researcher expressed that the integration of numerous technological tools disrupted the lesson’s natural flow. This is what the researcher recorded:

“The issue of excessive technology integration emerged as a challenge during the lesson, marked by the integration of multiple technological tools within a short timeframe. The lesson integrated a video, an animation, simulations from OLABS and PhET, as well as Wordwall and Kahoot. The transition from one technological tool to another consumed valuable lesson time.” (20th November, 2023, Observation Field Note, Line Number: 101–104).

During deliberations on the issue of excessive technology integration at the validity committee meetings, the validity committee members provided various recommendations to address this issue. In the subsequent implementations, the number of technological tools integrated into the lessons was significantly reduced. During the second implementation, only a video, an animation, a simulation, ESL Games Plus, and Kahoot were used. In the third implementation, the lesson incorporated only an interactive video, a simulation, and Kahoot. According to the researcher’s post-implementation reflection journal recorded at the end of the third implementation, the

lesson proceeded more smoothly with the reduced number of technological tools compared to the previous lessons. The researcher recorded the following:

“The lesson proceeded smoothly, and I was genuinely impressed by the positive impact that the integrated technological tools had on their understanding and enjoyment. I incorporated an interactive video, a 3D simulation, and Kahoot into the lesson. Unlike previous occasions, I did not use a plethora of tools this time, as the ones integrated proved to be sufficient in aiding the achievement of the instructional objectives.” (Researcher Reflective Journal, Ankara, 4th December, 2023, Line Number: 2–6).

Regarding the “preference for computer peripheral functionality,” some students expressed concerns regarding the functionality of the laptop mouse they were using. According to the students, the mouse’s functionality made it difficult for them to use: “The mouse on the computer did not work that well and was hard to use, but other than that, there was no problem” (Student 8–1st week’s Questionnaire).

Despite not being informed about the problem during the lesson, from the researcher’s investigation, it was discovered that the problem was not a hardware malfunction but rather a matter of preference related to the speed of the mouse:

“The issue regarding the laptop mouse not functioning optimally was investigated. On investigation, it was determined that the problem stemmed from a setting related to the cursor speed. Subsequently, the speed of the cursor was adjusted to ensure it moved slightly faster than before, resolving the problem.” (Observation Number 1, Date: 20th November, 2023).

“Difficulty in assessing individual students’ understanding” also emerged. During the second and third validity committee meetings, members pointed out the issue of utilizing collaborative assessment instead of assessing individual student understanding. They emphasized that assessing students collaboratively makes it difficult to determine each student’s individual comprehension. In the assessment activities conducted through group work in previous weeks, the researcher observed the students’ collaborative problem-solving processes and noted that they did not experience any difficulties in this regard; they were able to solve the assessment questions collaboratively and demonstrated effective peer interaction. While these group-based assessments supported social learning, collective reasoning, and the co-construction of knowledge, they did not allow for a clear determination of each student’s individual achievement of the course objectives. Measuring students’ independent performance would not only provide individualized feedback and opportunities for self-correction but also reveal their personal level of understanding without the influence of peer support. For this reason, the validity committee recommended conducting an individual assessment in the next class. This proposal was unanimously accepted by the committee, and an action plan was developed

accordingly for the following week. To address this, using Kahoot for individual assessments was suggested, allowing the students to participate individually using their mobile phones. Accordingly, provisions were made in the third lesson plan to use Kahoot to assess the individual understanding of the students. At the end of the third implementation, the individual understanding of the students was successfully assessed. This was made possible due to a model proposed by one of the validity committee members: “There is a “Bring Your Device/ Tablet” model. Students are informed beforehand to bring their tablet devices to class. It is explained that technology will be used in class that week, and they will need to bring their tablets to the classroom.” (Validity Committee Meeting No. 3).

The individual assessment phase ensured educational accountability by making each student’s performance clearly observable, traceable, and measurable. Because every student was required to respond independently, the process eliminated issues such as free-riding and enabled a fair evaluation of personal learning outcomes. In addition, the subsequent reflection and discussion activities allowed the social benefits of the group work phase to be retained, while the individual assessment added the necessary level of accountability to the overall evaluation design. Thus, the shift from collaborative to individual assessment was essential to align the evaluation process with both the cognitive objectives of the course and the accountability requirements.

DISCUSSION, LIMITATIONS, AND CONCLUSION

The use of videos sourced from YouTube offered visual and auditory elements that attracted, enhanced, and maintained the students’ attention during the science lesson, which ultimately improved their understanding of the scientific concept under study. This finding is consistent with the findings of the studies carried out by Breslyn and Green (2022) and Sherer and Shea (2011), in which they reported that YouTube videos have the potential to draw students’ attention and foster active participation more effectively than traditional learning environments, due to their multimedia content. Moreover, videos also played a major role in promoting active students’ participation by encouraging discussion, engagement, and cooperation through the incorporation of questions and periodic pauses, allowing the students to work out the solutions before proceeding.

Throughout the implementation of this study, animation was one of the valuable technological tools in the science lessons. The animations were mainly utilized to present abstract concepts to the students at the beginning of the lessons. The study of Barak, Ashkar, & Yehudit (2011) reports that animations help clarify abstract and difficult-to-understand ideas, facilitating the shift from abstract to concrete thought. In addition, the animations in this study were used to lay the foundation for subsequent instructional activities, particularly simulations, by providing step-by-step instructions on how to

carry them out. Burn (2013) and Ikwuka and Samuel (2017) also indicate its value in educational settings, especially for illustrating procedures that might be hard or impossible to describe conventionally. However, a downside observed while utilizing animations was the tendency to turn students into passive learners.

2D and 3D simulations are among the technological tools that were integrated into the science lessons to provide the students with hands-on activities that solidify their understanding of the scientific concepts being taught. By engaging with these simulations, the students were able to explore complex ideas more deeply and apply their knowledge in interactive ways. The students have expressed various views regarding these simulations, primarily centered on how they made the science lessons easier, understandable, and enjoyable. These findings were consistent with the findings of Wieman et al. (2010), who contend that simulations help students understand abstract concepts that are sometimes challenging for them to understand. According to Damassa and Sitko (2010), simulation technologies are useful instructional tools that are being used more frequently because they can produce impactful learning experiences. The students participating in the current study expressed that the 3D simulations helped them understand the concepts better and allowed them to visualize how the experiments were conducted. Elangovan and Ismail (2014) reported similar findings, where 3D simulations used during a biology lesson improved students' understanding, performance, and achievement.

Game-like tools and platforms such as ESL Games Plus, Wordwall, and Kahoot were integrated into the science lesson during the implementation phase of this study, specifically at the assessment stage. The integration of these tools elicited reactions from the students, ranging from enhanced engagement and motivation to improved understanding and enjoyment of lessons. These findings align with those of Chaiyo and Nokham (2017), Licorish et al. (2018), and Omar (2017), who reported that interactive game-based applications are increasingly being integrated into educational settings, highlighting their ability to establish relevant technology-enhanced teaching methodologies and boost students' overall learning experiences, motivation, and engagement. The students expressed appreciation for specific to Kahoot and frequently requested instructional activities that included it. Literature also reports positive results regarding integrating this tool into the learning process (e.g. Arif et al., 2019; Janković, Maričić, M., & Cvjetičanin, 2024; Mdlalose et al., 2022; Nadeem and Al Falig, 2020; Sabandar, Supit, & Suryana, 2018).

During the implementation, in which various technological tools were integrated into the science lessons, some challenges were encountered. A number of researchers have repeatedly noted that a major barrier to the integration of technology in education is time constraints (Al-Awidi and Aldhafeeri, 2017; Alfelaaj, 2016; Li and Walsh, 2010; Mumtaz, 2000). The

technology integration timeline was developed and integrated in this study. This strategy, which is supported by Dexter and Anderson (2002) as well as Lim and Khine (2006), places a strong emphasis on instructors working together to develop lesson plans and resources that use technology. By doing this, time restrictions that impede the successful integration of technology are reduced. Techno-centric distractions were one of the issues encountered during the implementation process. The technological tools integrated into the science lesson, especially the simulations, aimed at providing hands-on activities and improving students' understanding, but they ended up becoming a source of distraction. A similar issue was reported by Pérez-Juárez et al. (2023), who claimed that technology creates a paradox in students' lives by making it easier for them to participate in educational activities while also becoming a source of distraction from completing tasks. In the current study, some students completed a simulated task ahead of time and then used their laptops to browse the internet for unrelated purposes. This behavior was similar to what McCoy (2016) found in a study, which showed that university students were utilizing digital devices for non-task activities for about 21% of the class period. To mitigate this issue, selecting and integrating more challenging simulation activities to counteract the distraction and maintain students' interest throughout the lesson strategy was implemented. The excessive integration of technological tools into the instructional process also posed a challenge during the science lesson. Studies conducted by Parker et al. (2019) emphasize that when it comes to technology integration, quality matters more than quantity. Although the integration of numerous technological tools resulted in students expressing satisfaction and enhanced understanding, the overwhelming quantity may have impacted the efficacy and depth of the learning experiences. Therefore, to ensure that students have meaningful and lasting learning experiences, a more deliberate and selective approach to integrating technological tools is necessary, focusing on choosing a few that align perfectly with the instructional objectives. This strategic approach is in line with Strom's (2021) suggestion, which highlights how crucial it is for educators to exercise caution when using technological tools and to keep students' engagement in mind.

Throughout the science lessons integrated with various technological tools, the students expressed a range of views, insights, and preferences regarding the technological tools utilized. Participating students reported positive and enthusiastic reactions. They noted that these tools not only enhanced their understanding of scientific concepts but also created an enjoyable learning environment for them. These responses align with Carter et al. (2017), who found that students view technology as a way to make learning enjoyable, boost confidence, enhance skills, and improve academic performance while saving time and reducing boredom or frustration. Similarly, other studies reinforce these sentiments (e.g. Gedera and Zalipour, 2018; Jackman and Roberts, 2014; Öztürk, 2014).

The students who participated in this study were between 13 and 14 years old. The students in this study expressed strong support for the continuous integration of technological tools in their science learning experiences. These preferences reflect Generation Z's characteristics and their advocacy for technology in learning. These attributes align with findings from studies showing that Gen Z prefers visual learning (Cilliers, 2017), technology for interactions (Kushnir et al., 2013), quick access to information and entertainment (Vikhrova, 2017), and collaborative learning (Moore et al., 2017).

In this study, the “bring your device” model was applied, wherein parents were asked to permit their children to bring phones and tablets to school for educational activities. This model aimed to encourage students to use their personal devices in school. Typically, mobile phone use is prohibited in most Turkish schools. As a result, some students bring phones for emergency or personal use but leave them with the administration, retrieving them at the end of the day, while others do not bring phones to school at all. For this study, a message was sent to parents requesting permission for the students to bring their phones to school for this activity. A significant advantage of this model was that the students used devices they were already familiar with, eliminating the need to adjust settings, as was required when using school-provided laptops. This familiarity enabled the students to use their devices comfortably in class. This model aligns with the Bring Your Own Device (BYOD) or Bring Your Own Technology (BYOT) models (McLean, 2016). According to Falloon (2015), when parents support the BYOD model, they grant their children access to technology similarly to other learning materials like books. BYOD also helps schools reduce the financial strain of supplying technology (Cardoza and Tunks, 2014) and minimizes technical support demands (Nelson, 2012). In general, BYOD is adopted when schools lack sufficient personal devices or the IT infrastructure to monitor the students' activity throughout the day (Nelson, 2012). However, in this study, while sufficient infrastructure was available, accessing it required students to use a computer lab, which was not preferred for science lessons. As a result, the “bring your device” model was implemented in the students' regular classroom setting.

Limitations

First and foremost, the sample size was relatively small, comprising only eight students from a single implementation class, all of whom voluntarily participated. Secondly, the content scope was limited to specific science units related to forces and motion, speed, and the description of movement. Thirdly, the duration of the implementation was restricted to a 3-week period, with no follow-up conducted to examine the long-term effects of the technology integration on science teaching and learning. Future research could benefit from extending the implementation period to an entire academic semester to provide a more in-depth understanding of the sustained impact of educational technology. Furthermore, employing diverse research methodologies may yield a more comprehensive

perspective on how technology influences various dimensions of science education, including student engagement, conceptual understanding, and academic achievement.

Conclusion and Implications

The findings of the study highlighted the significant role of digital tools in enhancing the students' understanding of fundamental scientific concepts. Data collected from multiple sources consistently indicated that the purposeful integration of technological tools – such as interactive videos, animations, 2D and 3D simulations, and gamified applications – enriched the students' learning experiences. These tools not only increased the students' engagement but also facilitated hands-on learning, making science lessons more enjoyable and comprehensible. Despite these benefits, several challenges were identified in the implementation process, ranging from minor technical issues to more substantial issues like time constraints and technology-induced distractions. Nevertheless, the adoption of proactive and context-specific strategies for each challenge contributed to the effective instruction. The study emphasizes that the key to effective use of digital tools lies in aligning them with instructional objectives, ensuring their appropriateness for students' developmental levels, and embedding them purposefully across the lesson phases – introduction, development, and conclusion. This study provides a valuable example for practitioners by demonstrating how readily accessible digital tools can be used to enrich science lessons in authentic teaching and learning contexts. At the same time, the real challenges encountered during the use of these tools, the strategies developed through the action research process to address them, and the students' reflections, preferences, and perspectives contribute to the body of knowledge on technology use in elementary science education. These insights can guide both classroom teachers seeking practical approaches and researchers aiming to better understand the complexities of integrating digital resources into science instruction.

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ETHICS STATEMENTS

Permission was sought and obtained from the Anadolu University Social and Human Scientific Research and Publication Ethics Board before commencing the study (Date and Protocol number: October 17, 2023–633104). Permission was also secured from the Ministry of National Education before the study (Date and number: February 23, 2024–702152).

CONFLICTS OF INTEREST

The authors declare that they have no known competing interests to influence the work and the results reported in this study.

INFORMED CONSENT

Before the study, informed consents were obtained from all of the students, and subsequent permissions were acquired through the Parents' Informed Consent Form covering participation in the research, interviews, questionnaires, and overall involvement in the study.

DATA AVAILABILITY

The data that has been used is confidential.

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