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Online collaborative tools for science education: Boosting learning outcomes, motivation, and engagement

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Abstract

Background: Online collaboration tools have been identified as potentially effective means for enhancing student learning, motivation, and engagement in science education. However, their effectiveness in improving science education outcomes among middle school students remains uncertain.

Objectives: The study aimed to investigate the impact of online collaboration tools on science education outcomes among middle school students, focusing on learning achievement, engagement, and motivation.

Methods: A quasi-experimental design with a pretest-posttest control group was used in this study. A total of 60 eighth-grade middle school students were involved in the study, with both the experimental and control groups comprising 30 students each. The experimental group incorporated the use of digital collaboration platforms, including Asana, Slack, and Team Viewer, as instrumental components of group project execution and discussion in their science lessons. Conversely, the control group adhered to the current educational approach in Turkey, characterized by the employment of an inquiry-based learning strategy in their science instruction. Data was collected over eight weeks using a science achievement test, engagement scale, and science motivation scale.

Results: The experimental group demonstrated significantly higher post-test scores compared to the control group, suggesting that online collaboration tools positively impacted science education outcomes. Additionally, survey data indicated high levels of engagement and motivation among the experimental group students when using the online collaboration tools.

Conclusions: The findings support the notion that online collaboration tools can effectively enhance learning, motivation, and engagement in science education among middle school students. These results have significant implications for educators, educational institutions, policymakers, and curriculum developers. Further research is needed to examine the potential of these tools in various educational contexts and with different student populations. This will help broaden the understanding of how online collaboration tools can be integrated into diverse learning environments, potentially benefiting a larger number of students and further improving science education outcomes.

KEYWORDS
engagement, learning outcomes, motivation, online collaborative tools, science education

1 | INTRODUCTION

Science education plays a pivotal role in the contemporary world, fostering the necessary skillsets and knowledge base for students to comprehend and resolve intricate scientific and technological challenges (Huang et al., 2020; Kalogiannakis et al., 2021; Oliveira et al., 2019). Recent years have witnessed an escalating integration of technology within the realm of science education, characterized by a burgeoning interest in leveraging online collaboration tools (Rannastu-Avalos & Siiman, 2020; Salta et al., 2022). Functioning as web-based applications, such tools enable shared online activities like messaging, file sharing, and evaluation, fostering dynamic interactivity (Tarun, 2019). They not only promote inter-student communication and collaboration but also heighten student involvement and motivation. Furthermore, these platforms provide opportunities for students to apply their acquired knowledge to real-world situations, offering a myriad of benefits, from enhancing student engagement to facilitating practical applications (Hernández-Sellés et al., 2019; Khomokhoana & Kogeda, 2021; Sahakiants & Dorner, 2021; Yates et al., 2021). These real-time, interactive applications, which permit students to connect and collaborate among themselves and with educators, present a spectrum of opportunities (Jeschofnig & Jeschofnig, 2011; Widyahastuti et al., 2017). The incorporation of such tools in science education necessitates a collaborative process predicated on reciprocal interactions between the learner and the surrounding environment (Alismaiel et al., 2022; Feyzi Behnagh & Yasrebi, 2020). By providing students with a digital environment in which they can engage in authentic and meaningful learning experiences, online collaboration tools can connect learning to real-world problems and situations (Bonk & King, 2012).

In Turkey, the rapid advancement of digitization in education, driven by the initiation of multiple large-scale technological projects such as FATIH Project (Increasing Opportunities and Technological Improvement Movement) over the past two decades targeting the enhancement of K-12 education, has fostered a growing interest in the implications of online collaboration tools on student learning (Kurt et al., 2022). While the interest in utilizing online collaboration tools is growing in Turkey, and numerous studies have confirmed their effectiveness across various educational fields (e.g., Firmansyah et al., 2022; Müller, 2023; Park et al., 2023), the empirical evidence demonstrating their efficacy in science education remains limited (e.g., Abdillah et al., 2021; Gerard et al., 2022; Salta et al., 2022). To the best of our knowledge, there have been no studies conducted in Turkey regarding the use of online collaboration tools in science education. Accordingly, this study aims to address this gap by investigating the impact of online collaboration tools on science education outcomes among middle school students in Turkey.

Research questions and hypotheses:

The research questions for the study could be as follows:

1. How do online collaboration tools impact the science learning outcomes of students?

- Hypothesis 1: The use of online collaboration tools leads to improved science learning outcomes compared to traditional learning methods.

2. To what extent do online collaboration tools enhance student engagement and motivation in science education?

- Online collaboration tools significantly increase student engagement and motivation in science education.

The results of this study will have important implications for science education practices and for the integration of technology in the science classroom, providing insight into the potential benefits of online collaboration tools and informing the development of guidelines for their effective use in the classroom.

2 | LITERATURE REVIEW

2.1 | Online collaboration tools

Online collaboration tools comprise software applications and platforms that allow individuals or groups to collaborate and share information and resources in a virtual space. Their increasing popularity in recent years stems from their ability to provide a convenient means for individuals to collaborate, regardless of their geographical locations (Li & Mak, 2022; Saçak & Kavun, 2023; Samoylenko et al., 2022).

Within the education sector, these tools significantly enhance collaboration, engagement, communication, and teamwork among students, teachers, and instructors (Donaldson et al., 2017; Gopinathan et al., 2022; Khalil, 2018). Their adoption brings substantial benefits. For instance, they enhance student engagement by providing opportunities to cooperate, share resources, and engage in virtual activities (Khlaif et al., 2021; Qureshi et al., 2021; Sobko et al., 2020; Yates et al., 2021). A standout feature of these tools is their potential to improve critical thinking and problem-solving skills (Hursen, 2021; Hussin et al., 2018; Romero et al., 2014). By participating in a virtual collaborative environment, students can engage in meaningful discussions, understand varied perspectives, and refine their analytical skills (Männistö et al., 2020; Wang et al., 2020; Warsah et al., 2021). These tools also foster a sense of community, thereby increasing motivation and engagement (Jeong et al., 2019; Sarwar et al., 2019). Moreover, they strengthen teamwork and communication, essential skills for middle school students in their critical developmental stages (Gacs et al., 2020; Kyaw et al., 2019; Silalahi & Hutauruk, 2020; Tudor Car et al., 2019). Educators acknowledge the transformative potential of online collaboration tools. They not only streamline course management and foster real-time interactions but also offer constructive feedback mechanisms (Hadjerrouit, 2014; Thomas et al., 2009; Vu & Dall'Alba, 2007). Beyond these functionalities, these platforms usher in novel pedagogical methods and enable the creation of interactive teaching resources, thus elevating the learning environment (Ansari &

Khan, 2020; Hernández-Sellés et al., 2019; Vlachopoulos & Makri, 2019).

There's a diverse range of collaboration tools available, including virtual classrooms, communication platforms, online bulletin boards, learning management systems, virtual labs, and online libraries of simulations (Alam, 2022; Eom, 2023; Hassan et al., 2022; Jamshidi & Milanovic, 2022; Mattar et al., 2022; Tuhkala & Kärkkäinen, 2018; Veluvali & Surisetti, 2022). Prominent platforms include Google Classroom, Slack, Microsoft Teams, Padlet, Blackboard, Wikis, and Zoom. Each of these has been extensively studied and found effective for online learning and collaboration. For instance, Google Classroom facilitates assignment management and communication (Bervell et al., 2022; Delos Reyes et al., 2022; Tarteer et al., 2022), Slack promotes team collaboration (Fontes et al., 2022; Leonardi & Torchiano, 2022; Papathoma, 2022), Microsoft Teams offers comprehensive communication tools integrating with Microsoft Office (Al Enezi et al., 2022; Gotlib et al., 2022; Rajaram et al., 2022), and so on for the other tools mentioned, each serving a unique educational purpose.

However, while the advantages of online collaboration tools are manifold, they are not devoid of challenges. One of the most pressing challenges is the omnipresent digital divide – the disparity in access to reliable internet connectivity. Many online collaboration platforms are fundamentally dependent on uninterrupted internet connections, making them inaccessible to students and educators in areas with patchy or non-existent internet infrastructure (Khalil, 2018; Muuro et al., 2014; Taghizadeh & Ejtehadi, 2023). But the divide isn't just about internet connectivity; it also encompasses digital literacy. To make the most out of online collaboration tools, users must possess a certain level of digital proficiency. Some students, especially those from underserved backgrounds, may not have been exposed to the digital skills training essential for navigating these platforms effectively (Sánchez-Cruzado et al., 2021). Similarly, not all educators are adept or comfortable with the integration of these digital tools into their pedagogical repertoire, which can hinder the realization of the tools' potential benefits (Abdullah & Ward, 2016).

2.2 | Online collaboration tools in science education

Online collaboration tools have gained traction in the realm of science education (Chu et al., 2017; Donnelly et al., 2013; Lau et al., 2017). These tools, prevalent across various educational disciplines, enhance collaborative learning, communication, and teamwork in science education. For instance, Labster is a virtual laboratory platform allowing students to perform virtual experiments and simulations, thereby bolstering their grasp on scientific concepts (Dyrberg et al., 2017; Rodrigues, 2018). Edmodo, a learning management system, provides a digital space for students and educators to interact, collaborate, and access course resources (Ekici, 2017). SimBio Virtual Labs offers interactive simulations for science disciplines (Donnelly et al., 2013), and PhET Interactive Simulations is an expansive online library focusing on visually stimulating chemistry simulations (Moore et al., 2014). Kahoot! stands out as an interactive platform where educators can devise and disseminate quizzes, surveys, and games, serving as both an engagement and assessment tool (Donkin & Rasmussen, 2021; Khazanchi & Khazanchi, 2019).

Research underscores the positive influence of online collaboration tools on student engagement and learning in science education. Such tools enhance motivation, foster collaboration, and sharpen critical thinking, problem-solving, and creativity (Donkin & Rasmussen, 2021; Donnelly et al., 2013; Ekici, 2017; Khazanchi & Khazanchi, 2019). They also grant students immersive learning experiences, reinforcing their understanding of scientific principles. Notably, virtual simulations provide a safe environment for exploring scientific phenomena, enriching comprehension (Donnelly et al., 2013; Falloon, 2019). Platforms like Labster and SimBio Virtual Labs particularly elevate the learning journey by offering hands-on simulations that illuminate complex scientific concepts (Bodine et al., 2020; Lansverk et al., 2020). In Figures 1 and 2, various instances of online collaboration tools that are utilized in science courses are demonstrated.

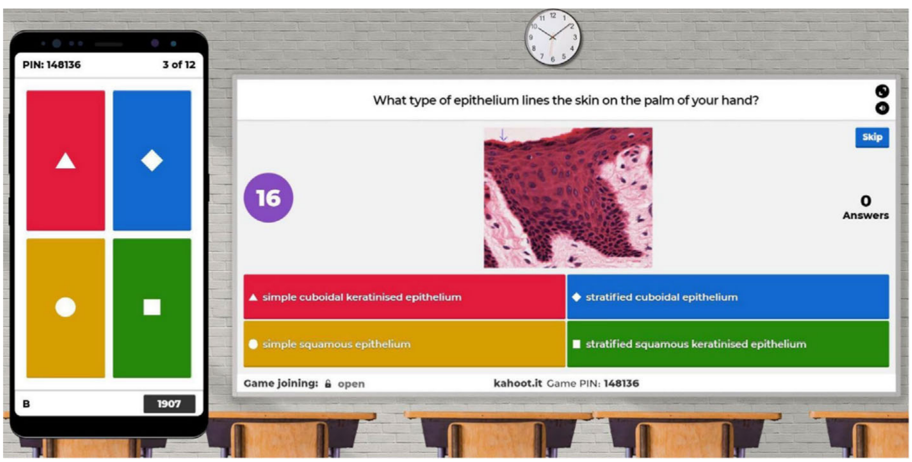

FIGURE 1 A sample of a publicly accessible quiz question on Kahoot! with an online response system used by students (Donkin & Rasmussen, 2021, p.576).

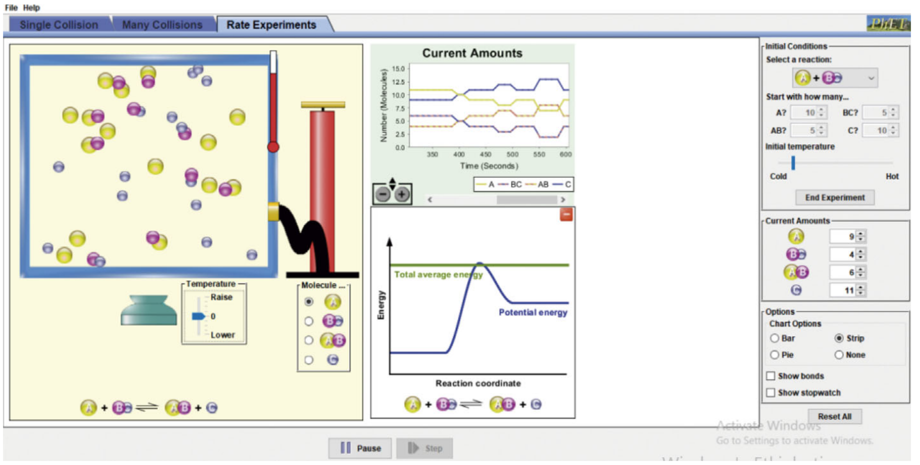

FIGURE 2 An instance of utilizing PhET Interactive simulations to teach reaction & rates (Rahmawati et al., 2022, p.315).

3 | METHOD

A quasi-experimental design with a pretest-posttest control group design was adopted to examine the effectiveness of online collaboration tools in enhancing science education outcomes, student engagement, and motivation of middle school students. The independent variable was the use of online collaboration tools in science education, while the dependent variables were the results of the students' science achievement, engagement, and motivation.

The study was conducted for the "Matter Cycles and Environmental Issues and Sustainable Development" units in the 8th grade science curriculum at a middle school in accordance with curriculum prepared by Turkish National Ministry of Education. The aim of this unit is for students to learn about environmental issues and to be able to offer solutions and gain knowledge and skills related to these issues. The following outcomes are aimed to be achieved from the students in this unit (Turkish National Ministry of Education, 2018).

1. Discuss the causes of global climate change and its potential consequences.

   a. The greenhouse effect is explained.

   b. In the context of global climate change, the impact on the future of the world and human life is questioned.

   c. Students are asked to express predictions of the impact of environmental problems on the future of the world in artistic ways.

   d. The students' ecological footprint is calculated using secure sites such as edu, org, and mil.

   e. The actions taken by world countries to prevent global climate change (e.g., Kyoto Protocol) are mentioned.

2. Show an emphasis on conserving resources in their usage.
3. Design projects for the efficient use of resources.
4. Explain the importance of separating solid waste for recycling.
5. Offer solution proposals by using research data on the contribution of recycling to the country's economy.
6. Indicate the problems that may be encountered in the future if resources are not used efficiently and offer solution proposals.

3.1 | Sample

The research was conducted at a co-educational middle school situated in the Central Anatolia region of Turkey. Incepted in 2005, this institution serves a heterogeneous student populace within an urban context. Notably, the school is equipped with cutting-edge technological infrastructure, inclusive of advanced computer labs and classrooms augmented with interactive smartboards, thereby elevating the pedagogical ambiance.

For this study, we employed a convenience sampling method, mainly due to the pressing time constraints our team faced. This approach yielded a sample of 60 eight-grade students, all of whom were pursuing science courses at a middle school situated in Turkey. To better understand our participant demographics: the age distribution spanned between 13 and 14 years. Gender-wise, the group was fairly balanced with 32 males and 28 females. Diving deeper into their academic backgrounds, the cohort's composition reflected a spectrum of academic achievements: 20% were distinguished as high achievers, a majority of 50% were categorized as average performers, and the remaining 30% needed academic improvement based on their latest assessments. An initial technological proficiency assessment revealed that around three-quarters (91%) of these students benefited from consistent internet and device access at home and exhibited a foundational grasp of digital tools. Conversely, the other 9% demonstrated limited exposure to such technologies.

Prior to the participant assignment, we conducted an initial assessment to evaluate each student's level of digital access and literacy. Importantly, this assessment also confirmed that participants had not been exposed to online collaboration tools in any previous units of science instruction, ensuring that the intervention represented a new experience for all students. This assessment was crucial for ensuring that both the control and experimental groups had a comparable level of digital proficiency, a key factor in our study of online collaboration tools. Following this assessment, we implemented a stratified random assignment process. Students were first grouped based on their digital literacy scores. Within each of these stratified groups, participants were then randomly assigned to either the control or the experimental group. This approach ensured that each group had a similar distribution of digital literacy levels, while still maintaining the principles of randomization. The stratification based on digital literacy scores allowed us to account for this variable, which could otherwise act as a confounding factor, potentially impacting the outcomes related to the effectiveness of online collaboration tools in science education. This method of stratified random assignment was employed to bolster the internal validity of the study, ensuring that any differences observed between the control and experimental groups could be more confidently attributed to the use of online collaboration tools, rather than disparities in digital literacy.

The study was structured around two distinct groups of participants: an experimental group and a control group, each comprising 30 students. The purpose of this bifurcation was to assess the impact of mandatory use of online collaboration tools on students' learning outcomes, motivation, and engagement, as compared to the conventional learning approach currently employed in the curriculum. In the experimental group, the use of online collaboration tools was a required component of the curriculum, ensuring consistent and uniform exposure of all participants to these digital resources. This group engaged in various interactive and collaborative activities facilitated by these tools as part of their science education.

Conversely, the control group continued with a traditional, non-tech-based science instruction approach. The curriculum for this group was rooted in the interdisciplinary, inquiry-based learning approach as outlined by the Turkish National Ministry of Education (2018). By adhering to these conventional instructional methods, the control group served as a foundational benchmark. This clear differentiation between the groups, with one employing mandatory online tools and the other following traditional teaching methods, was crucial. It enabled a more definitive comparative analysis, allowing the study to more effectively elucidate the causal relationship between the integration of online collaboration tools and the enhancement of learning outcomes in science education.

3.2 | Data collection process

The study received approval from the university's academic ethical review committee to ensure the protection of the participants' rights. To maintain confidentiality, the participants' personal information was kept confidential throughout the experimental process. Throughout the study, the researchers' role was multifaceted. Initially, they were responsible for participant recruitment and informed consent procurement. During the intervention, they observed student interactions, especially in the experimental group, offering technical assistance when needed. Furthermore, they administered the pre-tests, post-tests, and surveys, ensuring unbiased, consistent conditions for all participants. The study's data collection spanned a total of 8 weeks, with each week featuring 4 h of science class dedicated to the respective processes outlined below:

Week 1: Recruitment of participants.

During the initial week, participants were assigned through a process that involved sending emails to parents, teachers, and students. Following this, a group of 60 students was formed, divided equally into an experimental group and a control group, with each group consisting of 30 students.

Week 2: Preparation and administration of pre-test.

The second week of the study was allocated for the formulation and execution of the pre-tests. These initial assessments included science achievement test, student engagement scale, and science motivation scale. The science achievement test was used to reveal students' foundational knowledge and comprehension of scientific concepts. The structure of the tests included a blend of multiple-choice questions, encompassing the breadth of topics explored within the course. Furthermore, students' levels of engagement and motivation were appraised via student engagement scale and science motivation scale. Both the experimental and control groups were subjected to the pre-tests, with a stipulated completion time frame of 60 min.

Week 3–5: Implementation of the intervention.

The intervention, conducted to assess the impact of online collaboration tools on student learning outcomes, spanned 12 h over a period extending from the third to the fifth week. A blind study design was central to our methodology. Participants in the control group were deliberately not informed about the specific nature of the intervention being applied to the experimental group. This strategic decision was crucial to ensure that the control group's responses and behaviours remained unaffected by any preconceptions or biases about the use of online collaboration tools. In this context, the experimental group's instruction heavily incorporated the use of online collaboration tools, offering a distinct contrast to the control group's approach, which followed an inquiry-based learning methodology aligned with the standard Turkish curriculum. Despite these different instructional methods, both groups were aligned in terms of learning objectives, allowing for any differences in outcomes to be confidently ascribed to the use of online tools rather than discrepancies in educational aims. To maintain instructional consistency, the same educator taught both groups. However, educators assigned to the experimental group received additional training to effectively integrate online collaboration tools into their teaching, ensuring they could fully utilize the capabilities of these digital platforms.

In our study, a key focus was on ensuring equivalence in the instructional activities between the experimental and control groups. This involved maintaining consistent learning objectives and core content across both groups, while adapting the mode of delivery to suit their respective tools and methods. For instance, in a project that aimed to study local ecosystems, both groups were tasked with analysing ecosystem components, understanding species interdependence, and discussing human impacts on the environment. The experimental group, utilizing online collaboration tools, engaged with digital resources such as interactive maps and online databases. Their

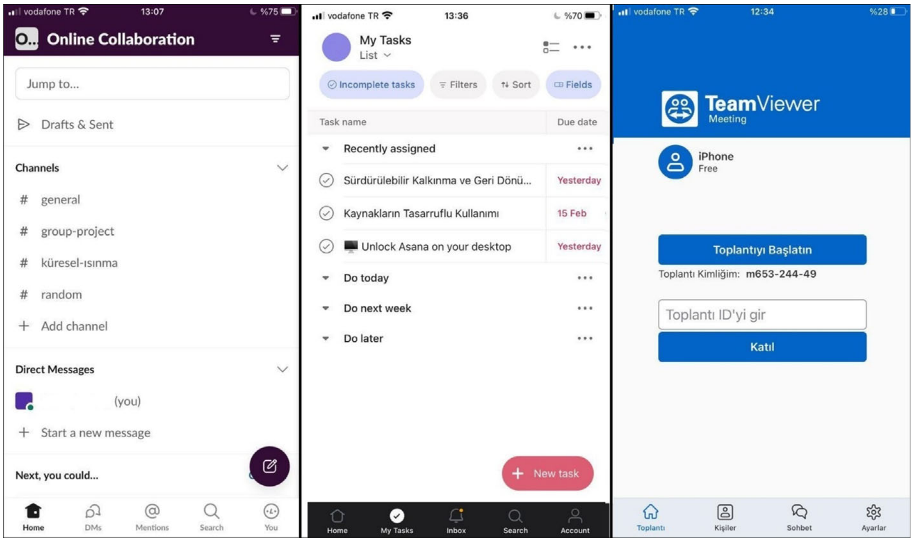

FIGURE 3 Examples of interfaces for applications that utilize group projects and online discussions (Slack, Asana, and TeamViewer apps).

collaboration took place on an online platform, where they shared findings and engaged in discussions within virtual breakout rooms. They were instructed to create a digital presentation of their findings, later shared with the class via video conference. Conversely, the control group, adhering to traditional instructional methods, used physical resources like textbooks and printed maps. Their collaboration was face-to-face, with discussions and project work occurring during class time. Their task was to create a physical poster or model representing their ecosystem study, which they then presented in a classroom setting. Despite the different methods of research, collaboration, and presentation, the core content and learning objectives remained consistent across both groups. This approach ensured that both groups engaged in equivalent learning activities from a pedagogical perspective, thus allowing for a fair comparison of the outcomes associated with each teaching methodology.

During the implementation, smartphones and earphones, provided by the researchers, were given to each student in the experimental group for the duration of the learning activity. To safeguard students' privacy, stringent data protection and usage restrictions were imposed on these devices, ensuring no unauthorized access or misuse. Students were not allowed to take these devices home, ensuring that all project and discussion-related activities either took place within the school premises or online under monitored conditions. The online collaboration tools used included platforms like Asana and Slack, which offer features like instant messaging, file transfers, and efficient message searching. Additionally, the TeamViewer app facilitated student participation in online discussions, both at school and home, boasting features like remote management, online meetings, web conferencing, and inter-smartphone file transfers. The interfaces of these apps are displayed in Figure 3.

Conversely, students in the control group engaged in group projects and face-to-face discussions within the classroom, collaborating directly with their peers and teacher.

Both groups, experimental and control, participated in a diverse range of projects, discussions, and debates. These exercises, from research projects focusing on environmental topics to creative tasks like mural creation, aimed to hone skills ranging from teamwork and critical thinking to argumentation and effective communication. For instance, projects included students working on creating public service announcements, envisioning sustainable futures through artwork, devising strategies to minimize water usage, and drafting persuasive essays on the merits of carbon reduction. Furthermore, discussions and debates were integral to the curriculum. Students frequently engaged in small group discussions or larger debates on topics like renewable energy usage, the ramifications of plastic waste on marine ecosystems, and the broader implications of human activities on the environment. The primary goal of this intervention was to augment the learning outcomes of the experimental group by offering them access to online collaboration tools. Simultaneously, the control group engaged in standard classroom activities, as outlined in the Turkish science curriculum. The overarching objective was to juxtapose the learning outcomes of these divergent teaching methodologies to discern efficacy and to deepen the understanding of student learning patterns, motivational shifts, and engagement variations. All data pertaining to the collection processes of teaching activities and materials used in both experimental and control groups are comprehensively presented in Table 1.

Week 6: Data collection through surveys.

The sixth week was dedicated to collecting data through surveys. The students in both the experimental and control groups were given a survey to complete at the end of the intervention. The survey was designed to assess their satisfaction with the intervention and their engagement of its effectiveness in enhancing their learning in science education.

Week 7: Administration of post-test.

The seventh week of the study was allocated for conducting the post-test. This assessment was designed to measure students' understanding of the science learning outcomes, as well as their levels of engagement and motivation following the intervention, utilizing the

TABLE 1 Comparative overview of teaching activities and materials used in experimental and control groups.

Activity type	Experimental group tools & methods	Control group methods
Recruitment	Emails to parents, teachers, and students	Same as experimental group
Pre-test administration	Science achievement test, Engagement & Motivation scales	Same as experimental group
Instructional method	Online collaboration tools	Standard curriculum method (Inquiry-based learning)
Tools used	Smartphones, earbuds, along with Asana, Slack, and TeamViewer apps	Direct peer & teacher collaboration in classroom
Discussions & debates	Online on platforms	Face-to-face in classroom
Group projects & creative tasks	Topics such as renewable energy, and plastic waste effects.	Similar topics as experimental group

same scales incorporated in the pre-test. The post-test was administered to both the experimental and control groups, allotting a 60-min completion period for each student.

Week 8: Data analysis.

The final week was dedicated to data analysis. The data collected through the pre-test, post-test, and survey were analysed using descriptive and inferential statistical methods. The results were then interpreted to determine the effectiveness of the intervention in enhancing science education outcomes.

3.3 | Instruments

For this study, the researchers used a pre-test and post-test assessment along with a survey questionnaire as the data collection tools. The pre-test and post-test assessments were employed to evaluate the students' level of knowledge, engagement, and motivation both before and after the interventions. To ensure the validity and understandability of each item translated into Turkish, a researcher studying learning motivation reviewed them, and a school teacher confirmed their comprehensibility for elementary school students. The pre-test and post-test assessments' validity was also confirmed by expert evaluations. The test items were scrutinized by three domain experts, each possessing over a decade of experience in teaching science education, information and communication technologies, and environmental issues. The survey questionnaire was pilot tested with a small sample of students to assess its clarity, relevance, and ease of use. Reliability was ensured by using a standardized administration procedure for both the pre-test and post-test assessments, as well as the survey questionnaire.

3.3.1 | Science achievement test

The Science Achievement Test, constituting 25 multiple-choice items, was employed to collect quantitative data. The aforementioned test utilized in this study is involved in the appendix. The test items were selected from the national examination item pool, and were related to the learning content. The results of the test were analysed to assess the effectiveness of the intervention and to determine whether there were any significant differences in achievement levels between the experimental and control groups. Overall, the science achievement test provided valuable data for the study and helped to determine the impact of the intervention on student learning in science. The test exhibited a reliability score of 0.85.

3.3.2 | Student engagement scale

This study used a scale called the student engagement scale to measure how students interact with learning activities. The scale developed from Wang et al. (2016) has 33 items, with 17 positively worded and 16 negatively worded questions, all of which are ordinal on a 5-point Likert scale, with "5" meaning "strongly agree" and "1" meaning "strongly disagree".

This study investigates four engagement dimensions which are: behavioural engagement, emotional engagement, cognitive engagement, and social engagement (Wang et al., 2016). The original scale developers defined these dimensions as follows. *Cognitive engagement* measures self-regulated learning, deep learning strategies, and applying cognitive strategies to comprehend complex ideas. A sample item is "*I think about different ways to solve a problem*." *Emotional engagement* measures the presence of both positive and negative emotional reactions towards teachers, peers, and classroom activities, as well as interest in learning and valuing the learning content. An example of an item is "*I enjoy learning new things about science*". *Social engagement* measures the quality of social interactions with peers and adults and the willingness to form and maintain relationships while learning For instance, consider the following item "*I try to help others who are struggling in science*". Finally, *behavioural engagement* measures participating in academic and class-based activities with positive conduct and the absence of disruptive behaviour. To illustrate, one item reads "*I put effort into learning science*." Cronbach's alpha for the behavioural, emotional, cognitive, and social engagement were 0.82, 0.88, 0.91, and 0.090, respectively.

3.3.3 | Science motivation scale

The Science Motivation Scale developed by Glynn and Koballa (2006) is a psychometric instrument designed to measure an individual's motivation to engage in science-related activities. Specifically, it assesses the level of intrinsic and extrinsic motivation that an individual has for learning about science and pursuing scientific activities. The scale was used to help researchers better understand the factors that influence people's motivation to learn and engage in science-related activities, and to identify potential barriers to participation in science. The Science

Motivation Scale has been widely used in research studies to assess students' motivation to learn science and to identify ways to improve science education (e.g., Çetin-Dindar & Geban, 2015).

The Science Motivation Scale is a 5-point Likert-type scale ranging from 'never' to 'always' consisting of a total of 30 items and includes six distinct components of motivation that are believed to impact an individual's willingness to engage in science learning and related activities (Glynn & Koballa, 2006). The first component measures an individual's intrinsic motivation to learn science, while the second component measures an individual's extrinsic motivation. The third component measures an individual's perceived relevance of learning science to their personal goals. The fourth component measures an individual's sense of responsibility and self-determination in learning science, while the fifth component measures an individual's confidence or self-efficacy in learning science. The final component measures an individual's level of anxiety about science assessment. Cronbach's alpha the Science Motivation Scale for was 0.87.

3.4 | Data analysis

In this study, the data analysis was conducted using the SPSS statistical software. The data was collected through pre- and post-tests and a survey administered to the experimental group. The pre- and post-tests aimed to assess the effectiveness of online collaboration tools in enhancing science education outcomes.

The quantitative data from the pre- and post-tests was analysed using inferential statistical methods including independent samples t-test and Analysis of Covariance (ANCOVA) to compare the scores of the experimental and control groups. A pre-test was conducted on both the experimental and control groups prior to the implementation of the intervention in order to determine if there was a significant difference between the two groups. In order to compare the experimental group with the control group, the data was analysed using ANCOVA. The level of significance was set at $p < 0.05$. If there was a significant difference between the groups, the effect size and 95% confidence interval were also calculated. Prior to conducting ANCOVA in this study, the Levene's Test of Equality of Error Variance was performed to test the homogeneity of the groups of data, ensuring that the statistical results were reliable (Timm, 2002). These analyses allowed for the determination of any significant differences between the groups and the assessment of the effectiveness of the online collaboration tools in enhancing science education outcomes.

4 | FINDINGS

4.1 | Initial insights: Assessing students' science learning, engagement, and motivation through pretest results

The study aimed to assess the impact of online collaboration tools on the science learning outcomes, student engagement, and motivation of middle school students. To this end, a pretest was administered to both the experimental and control groups before the implementation of the intervention (see Table 2). The experimental group showed a mean score of 3.47 with a standard deviation of 1.22 for learning outcomes, 3.78 with a standard deviation of 1.03 for student engagement, and 3.66 with a standard deviation of 1.01 for motivation. On the other hand, the control group's mean scores were 3.50 with a standard deviation of 1.15 for learning outcomes, 3.69 with a standard deviation of 1.20 for student engagement, and 3.62 with a standard deviation of 1.13 for motivation. The results of the pretest showed that there was no significant difference in the scores of the two groups with regards to their initial knowledge ($t = 0.022$, $p > 0.05$), engagement ($t = 0.138$, $p > 0.05$), and motivation ($t = 1.089$, $p > 0.05$) as shown in Table 3. This implies that both groups had similar levels of baseline understanding of the science concepts and that the comparison of the effectiveness of the online collaboration tools and traditional face-to-face instruction would be based on a fair comparison. The results of the pretest provide a solid foundation for evaluating the impact of the online collaboration tools on science learning outcomes, student engagement, and motivation.

TABLE 2 Mean scores and standard deviations for learning outcomes, engagement, and motivation in experimental and control groups in pre-tests.

Dimensions	Group	Mean	SD
Learning outcome	Experimental group	3.47	1.22
	Control group	3.50	1.15
Student engagement	Experimental group	3.78	1.03
	Control group	3.69	1.20
Motivation	Experimental group	3.66	1.01
	Control group	3.62	1.13

TABLE 3 Pretest score comparison between experimental and control groups.

Variable	*t*-value	*p*-value
Learning outcome	0.022	0.16
Student engagement	0.138	0.18
Motivation	1.089	0.36

4.2 | Uncovering the significance: Analysing the impact of online collaboration on science learning outcomes, student engagement, and motivation

In this study, the impact of using online collaboration tools on students' learning outcomes, engagement, and motivation in a science course was analysed. The results of Levene's test for equality of variances in the pre- and post-test scores of students' learning outcomes showed that the assumption of homogeneity of variances in the groups was met ($F = 0.12$, $p = 0.62 > 0.05$). This allowed for the use

Dimensions	Group	N	Mean	SD	F	p	η2
Learning outcome	Experimental group	30	3.97	1.02	3.56	0.021	0.05
	Control group	30	3.63	1.11			
Student engagement	Experimental group	30	4.13	0.91	3.42	0.034	0.05
	Control group	30	3.82	1.09			
Motivation	Experimental group	30	3.97	0.87	3.89	0.027	0.03
	Control group	30	3.71	0.96			

TABLE 4 Analysis of the science learning outcomes, student engagement, and motivation scores using ANCOVA.

of ANCOVA to be performed. The results of the ANCOVA showed that after controlling for the pre-test scores, the experimental group significantly outperformed the control group in learning outcomes ($F = 3.56$, 95% CI [62.3, 46], $p = 0.021 < 0.05$) with a medium effect size ($\eta 2 = 0.05$). The results demonstrated that students who used online collaboration tools for their learning performed better in terms of learning outcomes compared to those who followed a conventional learning approach.

Similarly, Levene's test for equality of variances for student engagement scores was $F = 0.74$ and $p = 0.44$, which was greater than 0.05. This indicated that the assumption of homogeneity of variances between the two groups was satisfied, and thus ANCOVA could be performed for analysis. The results showed that after controlling for pre-test scores, there was a significant difference in student engagement between the experimental and control groups ($F = 3.42$, 95% CI [3.97, 3.7], $p = 0.034 < 0.05$) with a medium effect size ($\eta 2 = 0.05$). The findings suggest that the use of online collaboration tools in learning led to significantly higher student engagement scores compared to the conventional learning approach.

Additionally, to check the basic assumption of the analysis of covariance, a test of regression homogeneity was conducted to compare the pre-test scores of the two groups ($F = 0.52$ and $p = 0.36 > 0.05$). This met the basic assumption of ANCOVA. A significance was reached ($F = 3.89$, 95% CI [57.9, 37], $p = 0.027 < 0.05$, $\eta 2 = 0.03$) for motivation scores. The study highlighted that students who used online collaboration tools for learning performed better in terms of motivation in a science course compared to those who followed the conventional learning approach. This implies that the utilization of online collaboration tools enhances students' motivation in science education. The statistical results are summarized in Table 4.

To put it simply, the findings of the study revealed a noteworthy improvement in the post-test scores of the experimental group compared to the control group. This outcome highlights the effectiveness of incorporating online collaboration tools in enhancing student learning outcomes in science education. The survey data further solidified the positive impact of online collaboration tools, as the students in the experimental group reported high levels of engagement and satisfaction with the tool's role in facilitating their learning and collaboration. These results signify the potential of online collaboration tools in not only improving student learning outcomes, but also boosting student engagement and satisfaction with the learning process.

5 | DISCUSSION

This research aimed to comprehensively examine the impacts of specific online collaboration tools—namely Asana, Slack, and Team Viewer—on middle school science students' learning outcomes, engagement, and motivation. The outcomes revealed a significant enhancement in learning metrics among students who actively utilized these digital platforms. Particularly notable was the experimental group's superior post-test performance compared to the control group, emphasizing the significant role these collaboration tools play in optimizing academic performance and fostering deeper student engagement and motivation.

One of the central benefits of these tools was their ability to support online discussions. These platforms offered an environment where students could debate, discuss, and derive insights collaboratively, thereby mirroring real-world problem-solving scenarios. Such dynamic discussions, facilitated by the tools, are crucial as they enable students to articulate their understanding, challenge misconceptions, and co-construct knowledge. Furthermore, these platforms introduced elements of project management, which are crucial for honing skills like task delegation, time management, and iterative feedback. By learning to manage projects in a digital space, students were positioned to better understand complex scientific concepts and processes, and were instilled with a sense of ownership over their learning journey. Importantly, while students benefited immensely, the effective integration of these tools into pedagogy requires adequate teacher training and support. Teachers need to be equipped with strategies to harness the full potential of these platforms, ensuring they're used to augment curricular objectives rather than as mere technological supplements. Continued professional development, peer sharing, and access to resource repositories can empower educators to design meaningful and impactful learning experiences.

Aligning with previous literature, this study resonates with the overarching consensus that collaboration and teamwork are pivotal to enhancing student learning, engagement, and motivation (Apicella et al., 2022; Chiu, 2022; Ng & Latife, 2022; Trust et al., 2023; Wong, Kan, & Chow, 2022; Yu et al., 2022). However, it also goes a step further by providing specificity regarding the importance of such tools within a middle school science context. While extant research has explored technology's role across various disciplines and educational tiers (e.g., Salas-Pilco et al., 2022; Syarifuddin & Atweh, 2022; Wekerle et al., 2022; Yu et al., 2022), this study stands apart with its emphasis on the middle school science arena. It underscores that, through these collaboration tools, students are not only granted a platform for enriched teamwork but are also nurtured to develop vital skills like critical thinking and adept problem-solving. Consequently, this research paves the way for future studies, accentuating the context-specific advantages of online collaboration tools across diverse educational landscapes.

5.1 | Implications

The findings of the study have several theoretical and practical implications. From a theoretical perspective, the introduction of online collaboration tools into the education landscape introduces a new layer of complexity to our understanding of teaching and learning dynamics. Traditionally, pedagogical approaches emphasized the human interactions and tangible resources present within the confines of a classroom. Now, with the advent of these digital platforms, we see a merging of the digital realm with the physical, creating hybrid learning environments that challenge our pre-existing theoretical models. These tools are not merely digital replicas of classroom resources; they represent a paradigm shift in how we view student engagement and participation. The always-on, interconnected nature of online tools means that learning is no longer restricted by time or space. This redefines our understanding of learning contexts, suggesting that cognitive development can be a continuous process, happening anytime and anywhere, rather than being confined to specific scheduled periods. The implications for theories on the optimal learning environment and time are profound.

Further, the ability of these tools to foster collaboration introduces nuances to our understanding of social learning. In a world where students can collaborate in real-time with peers across the globe, we are prompted to reconsider theories that hinge on face-to-face social interactions as primary drivers for cognitive development. The nature of digital interactions, the absence of physical cues, and the asynchronous communication modes prevalent in many online tools suggest that students might be developing new cognitive and socio-communicative strategies that have yet to be thoroughly explored in theoretical models. Moreover, the customizable nature of these tools, where content can be adapted to individual learners, prompts a reexamination of theories surrounding differentiation and individualized instruction. While the idea of tailoring instruction to individual needs isn't new, the scalability and precision offered by digital tools present a different dimension to this concept. The ability of technology to constantly assess and adapt to student needs in real-time pushes us to revisit and refine our theoretical understanding of learner-centered approaches.

From a practical perspective, the integration of online collaboration tools has the power to redefine the traditional classroom dynamics and structure. With these tools, the physical limitations of a classroom can become adaptable, providing educators the flexibility to offer lessons beyond their conventional settings. This transformation can lead to a blend of in-person and virtual learning, enhancing the overall teaching and learning experience. These tools also introduce diversified assessment techniques, allowing educators to harness digital quizzes, interactive projects, and other innovative methods to understand student progress. The instant feedback provided by such tools can greatly help in personalizing learning interventions.

Professional development and training emerge as paramount facets in this digital integration. The introduction of online tools necessitates a higher level of digital proficiency among educators. Therefore, institutions need to prioritize comprehensive training programs to ensure that educators are equipped to maximize the potential of these platforms. Beyond individual lessons, these online platforms can facilitate collaborative teaching, enabling educators to share best practices, partake in joint lesson planning, and potentially co-teach, breaking geographical barriers.

In terms of student engagement, online collaboration tools pave the way for more tailored and inclusive learning paths. Content can be adjusted to fit individual student needs, ensuring better engagement and comprehension. This aspect is particularly vital for students who may find traditional learning setups challenging. Furthermore, these tools offer a gateway to inclusive education. Their features, such as closed captions, audio descriptions, and adjustable reading speeds, can make educational content more accessible to students with special needs.

From an infrastructure perspective, there's a pronounced shift in budgetary considerations. Schools might need to realign their budgets to prioritize online platform subscriptions, improve internet infrastructure, and ensure that students have access to the necessary devices. On a positive note, the reduced dependency on physical materials hints at a more sustainable and eco-friendly approach to teaching.

Parental involvement and community engagement are also augmented through online collaboration tools. Platforms with integrated communication features can enhance the connection between educators and parents. This constant communication ensures that guardians remain updated on student progress, assignments, and other classroom activities. Furthermore, these tools can be instrumental in community-building, fostering forums or groups where stakeholders can discuss, share resources, and collaborate.

Lastly, the emphasis on online collaboration tools prepares students for the evolving digital landscape. By familiarizing themselves with these tools, students acquire more than just science knowledge; they also develop essential digital literacy skills. This ensures that they are not only navigating their present educational journey effectively but are also being equipped for future careers in an increasingly digital world. The implication here is clear: the integration of online collaboration tools is more than just a teaching enhancement; it's a forward-looking strategy to prepare students for the challenges and opportunities of the digital age.

5.2 | Limitations and suggestions for future researchers

The study had several limitations that should be considered when interpreting the results and planning future research. One of the major limitations was the limited sample size of the study. The study was conducted with a small sample of students, and the results may not be generalizable to a larger population. This means that the findings may only be applicable to a similar group of students, and cannot be extended to other populations. In order to increase the generalizability of the results, future researchers could consider conducting the study with a larger sample size. In addition, the study did not assess the long-term impact of online collaboration tools on student learning and engagement. The results of the study only provide a snapshot of the impact of these tools, and it is important to determine the sustainability of this impact over time. To address this limitation, future researchers could consider conducting long-term studies to determine the long-term impact of these tools on student learning outcomes. Finally, the study was conducted in a single learning environment, and the results may not be applicable to all learning environments. To address this limitation, future researchers could consider conducting studies in different learning environments to gain a better understanding of the impact of online collaboration tools in diverse educational settings. Overall, these limitations should be taken into consideration when interpreting the results of the study and planning future research in this area.

6 | CONCLUSIONS

This research comprehensively delved into the influence of online collaboration tools on learning achievements in science education among middle school students. The meticulous analysis of our collected data highlighted a significant enhancement in learning outcomes when these advanced digital platforms were integrated into the curriculum. Notably, students in the experimental group not only achieved higher scores but also demonstrated an improvement in their engagement and motivation, for the subject matter. These enhancements affirm the transformative power of online collaboration tools, positioning them as pivotal assets in modern science education.

Beyond the immediate improvements in learning outcomes, this study accentuates the broader implications of integrating technology in the educational landscape. It provides tangible evidence in support of the idea that technology, when used thoughtfully and strategically, can revolutionize the way students experience and internalize scientific concepts. In a world that is rapidly embracing digital transformation, understanding the synergy between technology and education becomes indispensable. Our findings contribute to this understanding, emphasizing the distinct benefits that online collaboration tools offer in the realm of science education.

Furthermore, while this research lays a strong foundation, it also underscores the need for continuous exploration in this domain. Future studies could expand on this by investigating the long-term benefits of these tools, analysing their adaptability across different educational settings, or even contrasting their efficacy with other emerging educational technologies.

AUTHOR CONTRIBUTIONS

Hüseyin Ateş: Investigation; methodology; resources; supervision; validation; writing – original draft; writing – review and editing. **Mustafa Köroğlu:** Investigation; methodology; supervision; writing – original draft; writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jcal.12931.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The study was conducted in accordance with the ethical guidelines of Kırşehir Ahi Evran University University's Institutional Review Board, which granted approval for the research (Approval No. 2023-122/15).

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APPENDIX A

A.1 | Science achievement test

1. What is the primary cause of global climate change?

   a. Natural disasters.
   b. Greenhouse gas emissions.
   c. Ozone layer depletion.
   d. Nuclear energy use

2. Which term describes the trapping of heat in the Earth's atmosphere?

   a. Ozone effect.
   b. Nuclear effect.
   c. Greenhouse effect.
   d. Solar effect

3. Which of the following can be a potential consequence of global climate change?

   a. Decrease in sea level.
   b. Less frequent extreme weather events.
   c. Increase in global temperatures.
   d. Increase in the ozone layer

4. How does the greenhouse effect contribute to global warming?

   a. By cooling the atmosphere.
   b. By trapping heat in the Earth's atmosphere.
   c. By reducing carbon dioxide levels.
   d. By increasing ozone layer thickness

5. How might global climate change affect human life in the future?

   a. Increased food security.
   b. Decreased natural disasters.
   c. Increased water availability.
   d. Increased health risks and diseases

6. What is your opinion on the Kyoto Protocol's effectiveness in mitigating global climate change?

   a. Highly effective.
   b. Moderately effective.
   c. Minimally effective.
   d. Not effective

7. What does conserving resources entail?

   a. Using as many resources as possible.
   b. Using resources inefficiently.
   c. Minimizing resource use.
   d. Maximizing resource use

8. What is the purpose of designing projects for the efficient use of resources?

   a. To deplete resources faster.
   b. To increase resource consumption.

c. To minimize resource wastage.
d. To increase resource wastage

9. Which of these would best demonstrate an emphasis on resource conservation?

a. Leaving the water running while brushing teeth.
b. Throwing away unused food.
c. Turning off lights when leaving a room.
d. Using single-use plastics daily

10. Why is it important to separate solid waste for recycling?

a. To increase landfill size.
b. To contribute to global warming.
c. To decrease resource conservation.
d. To reuse materials and reduce waste

11. How could the efficient use of resources positively impact the environment?

a. Increased pollution.
b. Decreased biodiversity.
c. Resource sustainability.
d. Climate instability

12. In your view, how effective is recycling in conserving resources?

a. Highly effective.
b. Moderately effective.
c. Minimally effective.
d. Not effective

13. What is the main advantage of recycling?

a. Increase in waste production.
b. Conservation of natural resources.
c. Increase in greenhouse gas emissions.
d. Increase in landfill size

14. How does recycling contribute to a country's economy?

a. Decreases employment opportunities.
b. Increases resource consumption.
c. Promotes sustainable growth.
d. Increases waste production

15. If you observed that your school was not efficiently recycling, what could be a potential solution?

a. Ignore the problem.
b. Increase the amount of waste produced.
c. Propose a school-wide recycling program.
d. Use more single-use plastics

16. What could be a future problem if resources are not used efficiently?

a. Decreased pollution.
b. Resource depletion.
c. Increased biodiversity.
d. Climate stability

17. How can you apply the concept of efficient resource use in your daily life?

a. By wasting more resources.
b. By using single-use items more frequently.
c. By implementing energy-saving practices.
d. By leaving the lights on all the time

18. Critically assess the effectiveness of separating solid waste for recycling.

a. Highly effective.
b. Moderately effective.
c. Minimally effective.
d. Not effective

19. What is the Kyoto Protocol?

a. A treaty to increase greenhouse gas emissions.
b. An international treaty to mitigate climate change.
c. An agreement to increase resource use.
d. A policy to reduce recycling

20. How does the Kyoto Protocol aim to address global climate change?

a. By promoting deforestation.
b. By increasing carbon dioxide emissions.
c. By setting binding emission reduction targets for countries.
d. By encouraging the use of fossil fuels

21. What is one way that countries can work to achieve the goals of the Kyoto Protocol?

a. By increasing their greenhouse gas emissions.
b. By reducing their reliance on renewable energy.
c. By implementing policies that promote the use of renewable energy.
d. By decreasing their recycling efforts

22. What are some potential consequences if the world fails to meet the objectives set forth in the Kyoto Protocol?

a. Decreased global temperatures.
b. Increased sea levels.
c. Decreased incidence of extreme weather events.
d. Improved air quality

23. Propose a strategy that could enhance the effectiveness of the Kyoto Protocol's objectives.

    a. Increasing fossil fuel consumption.
    b. Decreasing recycling efforts.
    c. Increasing deforestation.
    d. Promoting sustainable development practices

24. Based on your understanding, how effective are current global efforts in addressing climate change?

    a. Highly effective.
    b. Moderately effective.
    c. Minimally effective.
    d. Not effective

25. What is an ecological footprint?

    a. The amount of land needed to produce the resources a person or population consumes.
    b. The amount of fossil fuels a person uses.
    c. The number of trees a person plants in a year.
    d. The amount of waste a person produces.