An evaluation of student response systems in secondary mathematics classrooms

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Abstract: This study aimed to determine the effects of Kahoot! and Plickers for secondary school students to improve mathematics performance and learning engagement, while also analysing students' perceptions. This research was designed as a pre-test-post-test quasi-experimental study. 71 seventh-grade students who participated were divided into three groups: two experimental groups where Kahoot! (n = 25) and Plickers (n = 22) were deployed, and a control group (n = 24) where conventional learning was delivered. A mathematics performance test, learning engagement, and perception scale were used to collect the data. The findings showed the post-test mean scores of the mathematics performance and learning engagement were increased significantly in the three groups ($p < 0.05$) and the Kahoot! groups had a greater impact. Furthermore, most students had positive opinions of both Plickers and Kahoot!, noting their simplicity, creating enjoyable learning, encouraging participation, building self-confidence, keeping focus, and increasing competitiveness, although some students found them challenging, time-consuming, and presenting technical problems.

Keywords: Kahoot!; Plickers; mathematics performance; learning engagement; perception.

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1 Introduction

The COVID-19 pandemic in 2020 had a significant and widespread effect on Indonesian children's education, with most schools staying closed to mitigate the virus's rapid spread. According to UNICEF (2021), 80% of students participated in full-time home learning or hybrid arrangements, which included dropping off and collecting up assignments or attending school in a restricted period. Distance learning posed significant challenges for rural communities, where families often shared a single smartphone and faced financial strain from the cost of internet data, making the transition to remote education even more difficult (UNICEF, 2021). WhatsApp became the most widely used platform for distance learning, enabling teachers to assign tasks, share materials, and provide explanations; however, interactions were largely one-way, with students reporting minimal feedback from their teachers (UNICEF, 2021). This lack of engagement contrasts with Vygotsky's principles, emphasising the importance of meaningful interactions between teachers and students, where both roles are respected and valued in the learning process (Capone and Lepore, 2022). Unfortunately, the issue of limited engagement has persisted post-pandemic, with Novita et al. (2023) noting that many students continue to feel disconnected from their studies due to a lack of interactive and supportive learning environments, along with the need for more precise evaluations of their development and increased collaboration opportunities. Engagement, in this context, involves students' active participation through interactions, communication, and teamwork with teachers and peers, which are essential for effective learning (Balalle, 2024). When teachers prioritise engagement, they actively address students' questions and guide discussions that support learning while maintaining student responsibility (Capone et al., 2018; Capone and Lepore, 2022).

Engagement theory, as highlighted by Capone and Lepore (2022), offers a modern approach to teaching and learning in the information age by emphasising the role of

technology in enhancing interaction and fostering development. Technology-driven learning environments encourage creativity and communication, which are critical for promoting student engagement (Capone and Lepore, 2022). As the use of technology in education continues to grow, teachers must explore its opportunities and benefits to foster effective learning and motivate students to actively engage in learning activities (Dellos, 2015; Lebedeva et al., 2023; Muir et al., 2020). This focus on active engagement is crucial, as it significantly enhances learning outcomes and is essential for improving academic achievement (Deslauriers et al., 2019; Grove, 2019).

The student response system (SRS) is one of these technological innovations acclaimed for its potential to increase student engagement in the classroom (Ebadi et al., 2023; Heaslip et al., 2014; Muir et al., 2020; Raje and Tamilselvi, 2024; Wood et al., 2021). The use of an SRS in the classroom encourages student participation by allowing students to respond to questions from the teacher, receive feedback from the teacher regarding their understanding of the course materials during class, determine whether they are adhering to the course materials, and evaluate their understanding of the course materials in comparison to other students (Heaslip et al., 2014). SRSs allow teachers to ask their students multiple-choice questions, who can then respond individually using (for example) a handheld wireless transmitter, with the results being presented instantly on charts (Herrada et al., 2020). Furthermore, students can better comprehend their current skills by using an SRS to compare their performance to that of their peers and self-evaluate their strengths and weaknesses (Ebadi et al., 2023).

According to Göksün and Gürsoy (2019) and Raje and Tamilselvi (2024), several free applications are available for formative assessment, including Plickers (polling, exams and quizzes), Edmodo (LMS, exams, surveys, and indicators), Socrative (exams, surveys, gamification, indicators), Kahoot! (quizzes gamification, surveys and indicators), quizizz (quizzes and words, cultural games, etc.), Google Forms and Flubaroo (exams and indicators), Padlet, Mentimeter, and Edpuzzle (video quiz could be integrated into Edmodo). Review of prior studies in the literature indicates that the Kahoot! application is more commonly used as an SRS platform than similar tools (Göksün and Gürsoy, 2019; Kocak, 2022; Zhang and Yu, 2021). Kahoot! offers a fun way to conduct in-class evaluations, helping to break up the monotony while allowing teachers and students to measure students' understanding, and track the class's overall progress and individual learners' learning trajectories (Bawa, 2019; Licorish et al., 2018; Rajabpour, 2021). It engages students in an enjoyable learning process while fostering a competitive yet supportive environment for study (Dellos, 2015; Ebadi et al., 2023).

On the other hand, Plickers has emerged as an appealing tool that enhances classroom interaction, encourages active student participation, and addresses common issues found in other SRS tools while delivering its core benefits (Wood et al., 2021). The application helps increase engagement and active learning by giving students immediate feedback (Mshayisa, 2020), offering greater anonymity, and eliminating the need for students' personal devices as part of the technological setup (Wood et al., 2021). Using Plickers as a formative assessment tool is vital in cultivating an engaging and supportive learning environment that facilitates academic progress (Elmahdi et al., 2018). When thoughtfully applied, Plickers exemplifies how SRS tools can enrich the classroom experience by integrating best practices such as contingent teaching, scaffolding student knowledge, formative evaluation, and strategies that promote collaborative learning (Wood et al., 2021).

While the use of SRSs in education is expanding and the development of SRS tools continues to grow, no comparative study has yet provided a comprehensive analysis of the effectiveness of Kahoot! and Plickers as SRSs. Thus, an experimental study could offer valuable insights into their impacts. This study not only reviews existing literature but also presents the results of our own experiment, examining the effectiveness of Plickers and Kahoot! in mathematics performance, learning engagement, and students' perceptions. The findings have practical implications, helping to identify which SRS platform achieves the best outcomes when implemented in the classroom, particularly at the secondary school level. Furthermore, comparing these two SRSs can help educators identify the more effective tool for various teaching scenarios and objectives, considering students' needs and available resources.

2 Literature review

2.1 Learning engagement

Student engagement is frequently regarded as a key indicator of both personal development (Carini et al., 2006) and academic performance (Fuertes et al., 2023). It has been linked to positive learning outcomes, such as enhanced critical thinking and improved grades (Li and Xue, 2023). In the educational context, student engagement encompasses students' psychological, cognitive, emotional, and behavioural responses to the learning process, including their participation in both in-class and out-of-class academic and social activities, all of which contribute to successful learning outcomes (Balalle, 2024; Gunuc and Kuzu, 2015). Abla and Fraumeni (2019) also define engagement as the state of being emotionally, socially, and intellectually prepared to learn, and it is characterised by interest, involvement, and a desire to learn more.

Several components that affect student engagement, including motivation, social engagement, self-efficacy, instructor expectations, and views, may affect how well students do (Grove, 2019). According to Fredricks et al. (2004), engagement can be categorised as behavioural, cognitive, or emotional. The idea of behavioural engagement is focused on participation; it comprises involvement in social and extracurricular activities and is thought to be critical in academic success and avoiding dropout. Emotional engagement is believed to increase connections to an institution and affect motivation to finish the activity. It covers responses to academics, school, teachers, and classmates, on both the positive and negative aspects. Finally, cognitive engagement is built on the idea of commitment; it encompasses consideration and the willingness to make the efforts necessary to comprehend challenging ideas and master difficult skills (Fredricks et al., 2004). As noted by Gibbs and Poskitt (2010), relies on students being behaviourally present and emotionally comfortable and connected in class, making it fundamentally dependent on both behavioural and emotional engagement.

Student engagement is essential as it enhances learning and satisfaction, with students achieving more when actively engaged in class (Nepal and Rogerson, 2020). Engaged students are also more likely to perform better academically, as their high levels of effort, energy, and immersion in their studies make engagement a strong predictor of academic success (Fuertes et al., 2023). Engagement arises when students value and apply knowledge and learning (Attard and Holmes, 2020). In mathematics, this happens when students actively participate in tasks and view mathematics as a meaningful, valuable,

and practical discipline, both within the classroom and in real-world situations (Attard and Holmes, 2020).

Technology integration in the classroom has been recognised by Balalle (2024) as an effective strategy for enhancing student engagement. This approach extends learning beyond the classroom, creating additional opportunities for communication, collaboration, and exploration (Attard and Holmes, 2020). Furthermore, Gibbs and Poskitt (2010) noted that combining technology with popular leisure activities for deliberate educational purposes can make learning more relevant and impactful, especially for less-engaged students. As students grow more engaged and empowered within their learning community, they are more likely to experience positive outcomes, creating a cycle where their increased energy, effort, and engagement continually improve the learning environment (Bond and Bedenlier, 2019). The use of technology platforms like Kahoot! and Plickers increased student participation and motivation (Raje and Tamilselvi, 2024), made the learning process more dynamic compared to traditional methods (Kocak, 2022), and resulted in higher levels of affective, cognitive, and operative engagement (Attard and Holmes, 2020).

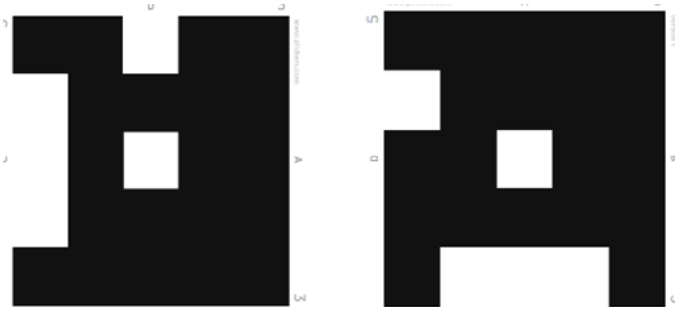
2.2 Plickers

Plickers is a free online classroom response system (CRS) app for Apple and Android devices that simulates a CRS that uses printed student response cards and is freely accessible by instructor-controlled computer technology (Chng and Gurvitch, 2018; Wood et al., 2017). Plickers is an easy-to-use tool that allows teachers to collect real-time data for formative and summative assessments without needing hardware devices, making it an ideal option for schools where not every student has access to technology (Chng and Gurvitch, 2018; Krause et al., 2017; Rila et al., 2019; Wood et al., 2021). Instead of requiring students to buy a clicker or use their personal devices, each student receives a simple card printed and distributed by the teacher at the start of the meetings (Wood et al., 2021). On the other hand, the teacher retains complete control over all technological aspects of the SRS, including a mobile device with a built-in camera, such as an iPad or smartphone, to house the free Plickers program and a computer with Internet access that can be projected to the entire class (Rila et al., 2019; Wood et al., 2021). Besides, Plickers can still work if the application has previously been downloaded to the device even if no wireless Internet access is available (Rila et al., 2019). From the perspective of a teacher, Wood et al. (2021) observed that Plickers provides a significantly user-friendly experience. The questions are professionally presented on the platform's website and mobile app. Student names can be copied and pasted to create class rosters. Question sets can be made for specific courses and scheduled for multiple sections within the same semester or between semesters – this differs from class management. Moreover, content development is more accessible for instructors by allowing them to share individual questions, question sets, or entire question packs via hyperlinks or an optional subscription service (Wood et al., 2021).

According to Chng and Gurvitch (2018), using Plickers in the classroom involves several steps. First, teachers who use Plickers to create tests do so before the instruction begins. These questions may be addressed verbally, shown on a screen, or distributed on paper. After a question is displayed, each student responds using a printed unique response card (see Figure 1). Each Plickers response card has a different printed pattern (similar to a QR code). The possible answers on the classroom screen are denoted by a

small letter, A, B, C, or D, printed next to each side of the pattern (Rila et al., 2019). Second, students hold their response cards up after rotating them, so their response is at the top. The teacher then scans the classroom using their mobile device's built-in camera (Rila et al., 2019). Third, the responses from students are immediately collected and saved on the website (plickers.com). The teacher may choose not to display individual responses during the question-and-answer sessions, but instead present the correct response and the group data. Students receive immediate feedback from this procedure to adjust their thinking, and the assessment process continues throughout the instructional delivery component of the daily activities (Mahoney and Hall, 2017). Additionally, teachers can evaluate students' understanding using the collected data and then determine whether to go on to the next lesson section or go back to clarify concepts most students did not fully understand (Chng and Gurvitch, 2018).

Figure 1 Examples of paper-based response cards that students can use to respond to multiple-choice questions by holding up the appropriate response alternative (identified by the number on the card)



Source: plickers.com

2.3 Kahoot!

Kahoot! is an innovative game idea developed as part of the lecture quiz research project, which started in 2006 at the Norwegian University of Science and Technology (NTNU). This free, game-based learning platform is compatible with various digital devices and seeks to make learning enjoyable for all topics and languages (Kalleny, 2020; Lin et al., 2018). The concept behind Kahoot! is to integrate an SRS with current technical infrastructure in schools, student-brought digital devices, social networking, and gaming, into one learning platform (Wang and Tahir, 2020). The platform supports a variety of media forms, including images and videos (Bicen and Kocakoyun, 2018), which can be added to quizzes to improve them, and the teacher can regulate the play speed of videos (Licorish et al., 2018). By combining visual materials with audio, music, and images, Kahoot! fosters a dynamic classroom environment conducive to discussion and interaction (Bicen and Kocakoyun, 2018).

Kahoot! is an engaging and educational web-based platform that facilitates learning through a quiz-like game format, enabling educators and course designers to incorporate educational content seamlessly (Bawa, 2019). The platform is user-friendly for educators (Siok et al., 2021), and its structure allows for easy measurement of outcomes via quiz-based gameplay simulations (Bawa, 2019). Teachers can present quiz questions as lecture slides, while students respond through a web browser on their mobile devices

(Leis et al., 2015). Students simply sign in using a game pin (Siok et al., 2021), and answer questions displayed on a shared screen using Internet-enabled devices like tablets, smartphones, or laptops (Bicen and Kocakoyun, 2018).

The Kahoot! game is structured as a point-based competition (Bawa, 2019), where students answer multiple-choice questions quickly and accurately, though the accuracy and speed of responses affect the points awarded (Wang and Tahir, 2020). The correct answers remain hidden until all students have responded, encouraging full participation (Wang and Tahir, 2020). Kahoot! efficiently aggregates and collects individual answers within minutes, reducing time constraints and allowing teachers to focus on creating quiz questions, presenting them, and engaging students in discussions around the correct answers (Licorish et al., 2018). Figure 2 illustrates students participating in a Kahoot! game.

Figure 2 Students play Kahoot! (see online version for colours)



Source: Authors

2.4 Implementing Kahoot! and Plickers in the classroom activities

Technology platforms like Kahoot! and Plickers, as formative assessments, can enhance student participation and motivation by providing them an opportunity to evaluate themselves compared to their peers and gain an accurate indication of their current skill level (Ebadi et al., 2023; Raje and Tamilselvi, 2024). Research highlights Kahoot!'s ability to promote learning retention (Janković et al., 2024) while fostering engagement, motivation, and enjoyment, making it a valuable classroom resource (Dellos, 2015; Licorish et al., 2018; Owen and Licorish, 2020; Rajabpour, 2021; Raje and Tamilselvi, 2024). From the teacher's perspective, Kahoot! maintains student engagement, delivers immediate feedback, and allows students to revisit challenging questions for deeper understanding (Rajabpour, 2021). It serves multiple purposes, such as assessing comprehension, conducting formative evaluations, or providing a fun break from routine lessons (Wang and Tahir, 2020). By breaking classroom monotony (Rajabpour, 2021) and incorporating 'realistic visualisations and stimulating activities', Kahoot! creates a dynamic learning environment beyond traditional textbooks (Balalle, 2024). Its

game-based features rapidly capture students' attention (Rajabpour, 2021), fostering enthusiasm, deeper understanding, and improved academic performance (Balalle, 2024). Additionally, Kahoot! supports customisation with tailored questions and problem-solving activities (Licorish et al., 2018) and is user-friendly, requiring no advanced technical knowledge, enabling quick and easy question creation (Curto Prieto et al., 2019).

Despite its benefits, Kahoot! has notable limitations, particularly in environments with unreliable internet access, which can significantly hinder its effectiveness. While its gamified structure is well-suited for subjects requiring high-energy interaction, it becomes less practical in resource-constrained settings where stable connectivity is lacking (Owen and Licorish, 2020). Connectivity issues, including overcrowded networks, often disrupt functionality and waste class time (Ebadi et al., 2023; Rajabpour, 2021). In contrast, in classrooms with stable internet and infrastructure, Kahoot! supports dynamic teacher-student engagement through competitive, knowledge-based games, accommodating various class sizes effectively (Lin et al., 2018). Features like instant feedback, including leaderboards, benefit low-ability learners by fostering quicker improvement compared to delayed feedback (Rajabpour, 2021) but may also induce stress in some students (Şad and Özer, 2019). Additionally, time allocation for answering questions requires careful planning; while quick responses enhance competitiveness and motivation, they can also cause frustration and hinder critical thinking (Chiang, 2020; Ebadi et al., 2023).

On the other hand, Muñoz et al. (2023) and Drushlyak et al. (2020) argued that Plickers is user-friendly for teachers and students, enhancing motivation and making the learning experience more enjoyable. From the standpoint of the teacher, Plickers has a low learning curve because of its thoughtfully designed website and application, which offers a clean and professional presentation of questions, easy creation of class rosters through simple copy-pasting, and the ability to share questions, sets, or entire packs via hyperlink or an optional subscription service, simplifying content creation (Wood et al., 2021). One key advantage of Plickers is its ability to foster classroom interactivity, providing immediate feedback that allows students to resolve confusion and deepen their understanding through class discussions (Muñoz et al., 2023). However, unlike Kahoot!, Plickers delivers individual feedback that is less immediate but focuses on maintaining anonymity, which helps reduce anxiety and fosters honest, peer-pressure-free discussions (Muñoz et al., 2023; Wood et al., 2021). This anonymity encourages all students to participate without feeling self-conscious (Chng and Gurvitch, 2018). Furthermore, Plickers may be more advantageous than Kahoot! in classrooms requiring simple, inclusive assessment methods, particularly in environments with limited access to individual devices (Clinkenbeard and Gross, 2023; Muñoz et al., 2023; Wood et al., 2021). Its reliance on printed cards rather than internet access or electronic devices makes it especially suitable for resource-constrained settings (Drushlyak et al., 2020; Muñoz et al., 2023). The application's reliance on laminated or printed cards, which are scanned by a single smartphone or tablet, reduces the intimidation factor for technology-challenged teachers or those new to using technology in the classroom, enabling them to focus more on teaching rather than setup (Kent, 2019). Additionally, Plickers places all technological components of the SRS under the teacher's control, minimising the need for advanced technological skills and reducing potential points of failure (Wood et al., 2021).

Table 1 Comparison of Kahoot! and Plickers

Feature	*Kahoot!*	*Plickers*
Type	Game-based learning platform	Real-time assessment tool
Device requirement	Requires students' devices (smartphones, tablets)	Only requires one device (teacher's smartphone)
Question format	Multiple choice, true/false, polls	Multiple choice only
Feedback	Instant feedback displayed to all students	Instant feedback for the teacher only
Engagement style	Competitive and gamified	Anonymous participation

Using Plickers in learning activities has several limitations that should be carefully considered. Muñoz et al. (2023) and Drushlyak et al. (2020) highlight that one major drawback is its restriction to multiple-choice questions, which limits its ability to evaluate more complex skills or open-ended responses. Additionally, teachers also need to be attentive to potential challenges during the card-scanning process (Kent, 2019). These challenges include students shaking their cards, holding them at inappropriate angles, glare from classroom lights, or blocking one another in crowded spaces (Kent, 2019). In larger classrooms, scanning cards can also lead to delays in presenting results, requiring extra time to complete the process (Muñoz et al., 2023). Students must also ensure that their cards are held correctly, with the chosen response clearly at the top, to avoid scanning errors (Kent, 2019). Furthermore, the application lacks individual monitoring, as it only provides a general overview of class performance rather than detailed feedback for each student, which can be a disadvantage in certain educational contexts (Muñoz et al., 2023). Other limitations include the fact that formulas cannot be directly included in question text or answers; instead, they must be presented as drawings and that exams can only contain five questions, which means that numerous tests must be administered to cover more material (Drushlyak et al., 2020).

3 Rationale of the study

As highlighted earlier, student engagement is crucial for learning and academic success (Fuertes et al., 2023), and tools like Kahoot! and Plickers contribute to making learning more interactive and enjoyable (Dellos, 2015; Drushlyak et al., 2020; Licorish et al., 2018; Muñoz et al., 2023; Owen and Licorish, 2020; Rajabpour, 2021; Raje and Tamilselvi, 2024). Plickers, which uses printed response cards, is ideal for classrooms without internet access (Kent, 2019), but its limitations, such as supporting only multiple-choice questions and being difficult to manage in larger classrooms (Muñoz et al., 2023), must be considered. Kahoot!, a game-based platform incorporating media like images and videos, fosters competitive learning (Chiang, 2020; Ebadi et al., 2023) but requires student devices and reliable internet (Owen and Licorish, 2020). Both tools enhance participation, with Kahoot! offering a more dynamic learning experience (Lin et al., 2018) and Plickers being better suited for low-technology environments (Wood et al., 2021).

Given the impressive outcomes of SRSs, research continues to determine which SRS platform accomplishes the best outcomes. Among SRSs platforms, Kahoot! and Plickers were widely recognised for their classroom implementation in different educational

settings. A systematic review by Kocak (2022) highlighted the reasons for using Kahoot! in classrooms, emphasising its accessibility as a free platform, its ease of use for students, its ability to create a fun and engaging learning environment, and its effectiveness in boosting student participation. This tool is a great addition to the classroom because it not only facilitates the learning process but also encourages active engagement and strengthens the positive relationships between students (Curto Prieto et al., 2019). Similarly, Plickers has been noted for its user-friendliness (Drushlyak et al., 2020; Muñoz et al., 2023), ability to provide immediate feedback, support in deepening student understanding (Muñoz et al., 2023), reduction of student anxiety (Muñoz et al., 2023; Wood et al., 2021), and minimised reliance on advanced technology (Drushlyak et al., 2020; Muñoz et al., 2023; Wood et al., 2021). While separate studies have explored the effectiveness of Kahoot! and Plickers on various cognitive and affective outcomes, there remains a gap in comparative research examining these platforms alongside traditional teaching methods and other educational technologies. Additionally, most studies on using SRSs in education have been conducted at higher education levels (Kocak, 2022). This was confirmed by Wang and Tahir (2020), who found that only 4% of the 93 studies they evaluated focused on applying Kahoot! in secondary education. Additionally, Kocak (2022) highlighted that most SRS studies have been conducted in fields such as medicine and language education, particularly English, with only one out of 77 studies exploring the use of SRSs in mathematics education.

Despite their shared goal of promoting interactive learning, Kahoot! and Plickers have distinct design features that may affect their effectiveness (refer to Table 1). The comparative analysis highlights how each tool supports or hinders classroom inclusivity. Kahoot!'s reliance on individual devices might create disparities if some students lack access to technology and reliable internet connectivity (Ebadi et al., 2023; Şad and Özer, 2019), whereas Plickers' card-based system, which requires minimal technology resources, can promote inclusivity by ensuring equal participation among all students (Muñoz et al., 2023; Wood et al., 2021). In certain situations, using a combination of both tools may be the most effective approach. Understanding the strengths and weaknesses of each tool allows teachers to customise their teaching approaches. They can select the tool that best matches their pedagogical goals and the specific needs of their students. By identifying the context in which each tool performs best, teachers can strategically integrate both tools to achieve optimal outcomes. This approach enables educators to determine the most appropriate tool for their teaching objectives and the specific needs of their students. Through a comparative analysis of Plickers and Kahoot!, developers might gain valuable insights regarding potential improvements and get inspired to design new features that combine the strengths of both platforms. This feedback fosters the development of more effective educational technologies that are better aligned with the needs of educators and students.

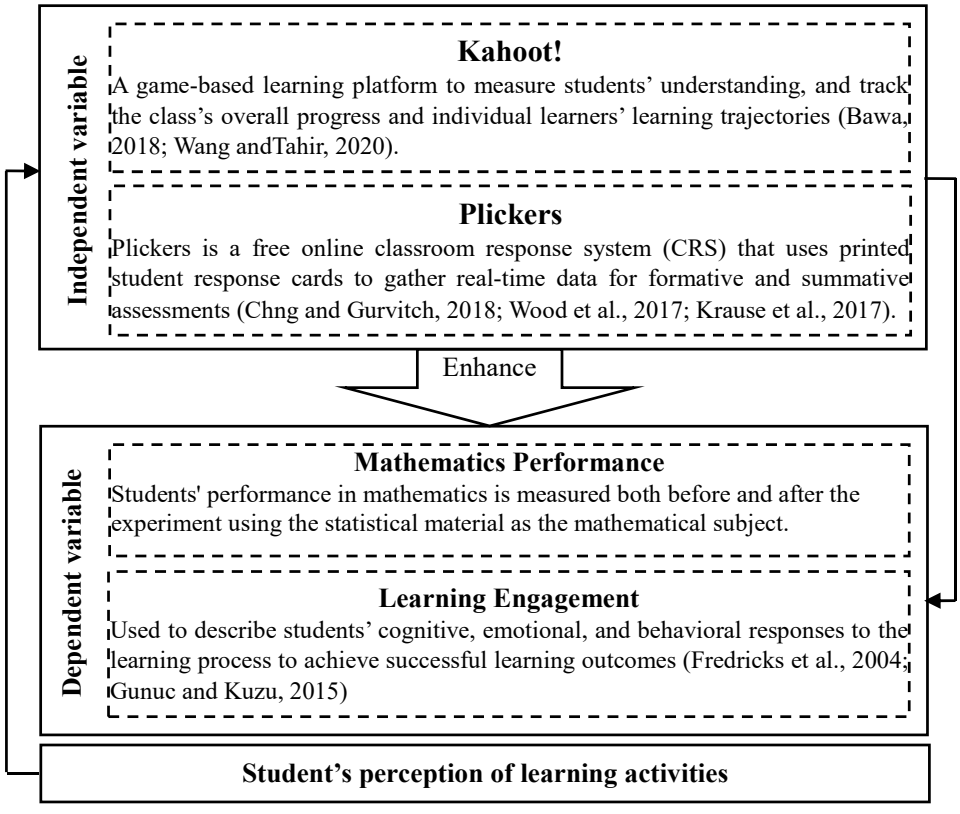
Building on the identified research gap, this study focuses on two widely accessible SRSs – Plickers and Kahoot! – which are freely available and are able to enhance student performance and engagement in secondary school classrooms. To evaluate the effectiveness of the proposed approach, an experiment was conducted to examine mathematics performance, learning engagement, and students' perceptions. The conceptual framework of this study is presented in Figure 3. The research questions were as follows.

1 What are the differences in mathematics performance among students in the three groups (Kahoot!, Plickers, and control group)?

2 What are the differences in learning engagement among students in the three groups (Kahoot!, Plickers, and control group)?

3 How do students' perceptions of learning mathematics differ when using Kahoot! compared to Plickers as SRSs?

Figure 3 Conceptual framework



Source: Authors

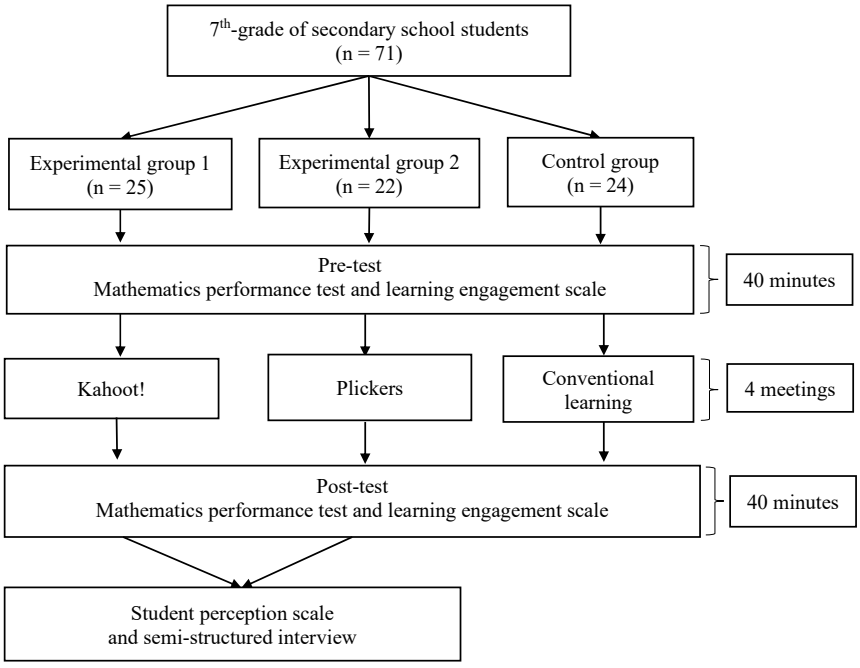
4 Methods

4.1 Study design

This study applied a quasi-experimental design, which was used to compare students' experiences of learning mathematics using Kahoot! and Plickers as SRSs. During the research, one experimental group used Kahoot! while the other used Plickers, and a third control group used neither. At the end of the lesson, the experimental group students completed four separate assignments utilising Kahoot! and Plickers as assessment tools, respectively. The control group used 'pencil and paper' to complete the test at the end of

meetings. Both a performance test and a learning engagement survey were given to students before and after the intervention. Then, an adapted questionnaire about students' perceptions was given to the participants after the learning experiment was completed. Students subsequently participated in a semi-structured interview to gather in-depth perspectives on using Kahoot! and Plickers. The research procedure is presented in Figure 4.

Figure 4 Experimental procedure



Source: Authors

Quantitative data for the study were gathered through mathematics performance test scores and responses to learning engagement and perception questionnaires. This process involved systematically collecting and analysing numerical data, including pre and post-test results for the dependent variables: mathematics performance and engagement. By utilising established measurement tools and statistical techniques, the quantitative phase aimed to determine the statistically significant effects of both SRS platforms on students' performance, engagement, and perceptions. This approach strengthened the generalisability and broader relevance of the study's findings. To complement this, qualitative data were collected through semi-structured interviews, offering deeper insights into participants' experiences with Kahoot! and Plickers during the learning process. This phase explored the subjective aspects of learning, providing detailed narratives that enriched the understanding of the quantitative results and offered a more comprehensive view of the study's outcomes.

4.2 Participants

The study used a purposeful sampling method, focusing on a public secondary school in Indonesia with which the researchers collaborated. This selection was influenced by Gibbs and Poskitt (2010) observation that students aged 10–15 are more engaged when learning is fun, varied, and challenging, and incorporating technology and popular leisure activities into lessons can make learning more meaningful, particularly for less-engaged students. Additionally, during the middle years, students are expected to take increasing responsibility for their education, reflect on their progress, showcase their strengths, and actively participate in class and school activities (Manitoba-Education-and-Training, 2017).

The study included 71 seventh-grade students, divided into three groups: Kahoot!, Plickers, and the control group. The researcher selected one class out of the three for the Kahoot! group, considering most students there can afford Internet data plans and have smartphones. Furthermore, researchers chose the Plickers and control group at random since only the teacher used a smartphone when using Plickers. All classes were instructed by the same teacher to maintain consistency, and none of the students had prior experience using Kahoot! or Plickers in a classroom setting.

The Kahoot! group consisted of 25 students (10 men and 15 women), the Plickers group consisted of 22 students (12 men and 10 women), and the control group consisted of 24 students (12 men and 12 women). There were differences in the numbers of students in each group because some students only completed the pre-test or post-test in mathematical performance and learning engagement. Then, seven students from each experimental group volunteered for the interview following the end of the learning experiment.

4.3 Data collection

4.3.1 Mathematics performance test

The test measured students' mathematics performance before and after the experiment. A higher score means a higher level of mathematics performance. A pre-test/post-test experimental and control group research design was employed for the study. Pre- and post-tests were conducted for each group. A pre-test was administered to determine the equivalence of all the groups. At the end of the treatment period, a post-test was administered to evaluate the effectiveness of the treatment on students' mathematics performance. The questions for both tests were the same. All the participants were invited to take the pre-test before the lessons as well as the post-test after the completion of the lessons.

The statistical material is the mathematical topic examined in this study. The test consisted of 8 items, including multiple-choice questions (2 items) and essay questions (6 items). The researcher examined the validity of this test instrument in measuring students' performance in mathematics through discussions with two mathematics teachers before the experiment. Then, a pilot application of the test was conducted with 30 eighth graders because they had already studied statistics in seventh grade. The characteristics of multiple-choice questions were as follows: reliability test (r) was 0.744; item validities were 0.888 and 0.896; discrimination powers (DP) were 0.533 and 0.6; and difficulty indices (DI) were 0.733 and 0.7. Furthermore, the characteristics of the

essay questions were as follows: reliability test (r) was 0.841; item validity (t) was $0.711 \leq t \leq 0.811$; DP was $0.311 \leq DP \leq 0.444$; and DI was $0.267 \leq DI \leq 0.767$. As a result, all eight performance test items could be used in the research.

4.3.2 Learning engagement scale

Students were asked to complete a questionnaire to ascertain their learning engagement before and after the learning process. The indicators of learning engagement included students' focus, involvement, and desire to learn further during the lesson. The student engagement scale was adapted from Leis et al. (2015) and consisted of three dimensions: social, emotional, and cognitive (13 items). The survey was then translated into Indonesian. The questionnaire items contained positive and negative statements. In accordance with Leis et al. (2015)'s questionnaire, the statements were anchored using a 4-point Likert scale rating (1 = no, not at all true, 2 = a little true, 3 = often true, 4 = yes, very true).

A pilot application of the test was conducted with 30 eighth graders. The resulting Cronbach's alpha score was 0.792, and the validity of the items was higher than 0.77. These values translated to good internal consistency; therefore, the engagement scale used was reliable and valid.

4.3.3 Student perception

The students' perception of Kahoot! and Plickers was measured by a questionnaire adapted from Mshayisa (2020), Shana and Abd Al Baki (2020), Chiang (2020), and Siok et al. (2021), and consisted of 15 items. Plickers was used by Mshayisa (2020) and Shana and Abd Al Baki (2020) in their research, whereas Kahoot! was used by Chiang (2020) and Siok et al. (2021). Then, the researchers combined the items from those four studies to compare the results. The questionnaire aimed to identify what the students assumed about the learning intervention. A 4-point Likert scale rating system was used to anchor statements (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). No neutral point was included in the questionnaire to get the respondents to voice an opinion. Negatively worded items were later reverse-coded.

In addition to the questionnaires, a 10-minute semi-structured interview was used to get the student's perspectives on the learning process. The interview questions were adapted from Muir et al. (2020), and then the questionnaire and interview questions were translated into Indonesian to gain deeper insights into participants' experiences when using Kahoot! and Plickers in the learning process. Furthermore, the interview results were compared with the students' perception results.

4.4 Data analysis

Multivariate analysis of variance (MANOVA) statistics analysis was used to examine the difference in students' mathematics performance and learning engagement between the three groups (Kahoot!, Plickers, and control group). The significance level was set to 0.05. The data collected from the results of the questionnaire and test were processed through these three stages:

1 score students' answers referring to answer key and guidelines

2 statistics assumption trial, namely normality, multicollinearity, and homogeneity

3 MANOVA.

Meanwhile, the qualitative data gathered from the semi-structured interviews were evaluated based on the frequency with which the students responded to each question.

5 Results

Based on the study's purposes and the nature of the collected data, the study findings were obtained with mixed-design MANOVA. The prerequisites for this test and the consistency of the research data with these prerequisites were as follows.

The normality of the dependent variables (performance and engagement) was analysed with the Shapiro-Wilk test, and it was observed that the variables exhibited normal distribution ($p > 0.05$). The multicollinearity of the dependent variables (performance and engagement) was examined using Pearson's correlation. The results showed that a meaningful pattern of correlations was observed among all of the dependent variables ($r_{pre\text{-}test}$ [71] = 0.688, $r_{post\text{-}test}$ [71] = 0.696, all correlations were positive and in the moderate range; $p < 0.001$). The homogeneity of variance-covariance matrices was tested with Box's test of equality of covariance matrices. The confidence level was set at 95%. As a result, it was observed that the variance-covariance matrices were statistically equivalent (*Box's M* = 7.071, $F_{pre\text{-}test}$ [6,106526.551] = 1.128, $p = 0.343$; *Box's M* = 4.481, $F_{post\text{-}test}$ [6, 106526.551] = 0.715, p = 0.638). Furthermore, when Levene's test of equality of error variances was examined, it was observed that the error variances of both dependent variables were equal ($F_{performance\text{-}pre\text{-}test}$ [2, 68] = 1.243, $p = 0.295$; $F_{performance\text{-}post\text{-}test}$ [2, 68] = 1.035, $p = 0.361$; $F_{engagement\text{-}pre\text{-}test}$ [2, 68] = 2.202, $p = 0.118$; $F_{engagement\text{-}post\text{-}test}$ [2, 68] = 1.414, $p = 0.250$).

Since the requirements for MANOVA were met, mixed-design MANOVA was conducted in the study. The first and second research objectives were evaluated using the MANOVA results. Specifically, whether Plickers and Kahoot! instructional methods led to a change in mathematics performance, and the students' learning engagement in experimental groups was analysed with this test.

5.1 Before intervention

In this study, the null hypothesis (H_0) was that there was no significant difference between the mathematics performance and learning engagement of students using Kahoot!, Plickers, and students from the control group. The confidence level was set at 95%. According to the results of the MANOVA (refer to Table 2), H_0 was accepted for the pre-test score for mathematics performance and learning engagement based on the learning method, $F_{[4,132]} = 0.025$, $p = 0.999$; *Wilks' lambda* = 0.998.

Table 2 MANOVA result for pre-test scores

Effect		*Value*	*F*	*Hypothesis df*	*Error df*	*Sig.*
Group	Wilks' Lambda	0.998	0.025b	4.000	134.000	0.999

Source: Authors

Similarly, the learning method showed no significant effect on mathematics performance, $F_{[2,68]} = 0.021$, $p = 0.979$, nor on learning engagement, $F_{[2,68]} = 0.008$, $p = 0.992$, as shown in Table 3. Overall, H_0 was accepted, indicating that there were no significant differences in mathematics performance or learning engagement across the learning methods (Kahoot!, Plickers, control group).

Table 3 Tests of between-subjects effects

Source	*Dependent variable*	*Type III SUM of squares*	*df*	*Mean square*	*F*	*Sig.*
Group	Performance pre-test	0.405	2	0.203	0.021	0.979
	Engagement pre-test	0.483	2	0.242	0.008	0.992
Error	Performance pre-test	663.482	68	9.757		
	Engagement pre-test	1988.137	68	29.237		

Source: Authors

RQ1 What are the differences in mathematics performance among students in the three groups (Kahoot!, Plickers, and control group)?

5.2 After intervention

For the post-test scores of students' performance and engagement, the H_0 was rejected, indicating a significant difference in mathematics performance and learning engagement across the learning methods (Kahoot!, Plickers, control group), $F_{[4,134]} = 8.016$, $p < 0.001$; *Wilks' lambda* = 0.651, $\eta_p^2 = 0.193$, as shown in Table 4. Further analysis revealed a significant effect of the learning method on mathematics performance, $F_{[2,68]} = 13.373$, $p < 0.001$, $\eta_p^2 = 0.282$. with detailed results presented in Table 5. These findings confirm that the learning method significantly influences mathematics performance.

The Scheffé method further demonstrated that mathematics performance differed significantly between the learning methods, as shown in Table 6. Specifically, students in the Kahoot! and Plickers classes performed significantly better than those in the control group ($p < 0.001$ and $p = 0.024$, respectively), while no significant difference was found between Kahoot! and Plickers classes ($p = 0.093$). Moreover, students' learning engagement in the Kahoot! and Plickers classes significantly differed from the control class, with significance levels of < 0.001 and 0.028, respectively. Applying this same procedure to the classes of Kahoot! vs. Plickers comparison, the results also indicated a statistically significant difference ($p = 0.040$, which is less than 0.05).

Table 4 MANOVA results for post-test scores

Effect		*Value*	*F*	*Hypothesis df*	*Error df*	*Sig.*	*Partial Eta squared*
Group	Wilks' Lambda	0.651	8.016b	4.000	134.000	< 0.001	0.193

Source: Authors

Table 5 Tests of between-subjects effects for post-test scores

Source	*Dependent variable*	*Type III sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Partial Eta squared*
Group	Performance post-test	155.819	2	77.909	13.373	< 0.001	0.282
	Engagement post-test	889.941	2	444.970	15.076	< 0.001	0.307
Error	Performance post-test	396.153	68	5.826			
	Engagement post-test	2006.989	68	29.515			

Source: Authors

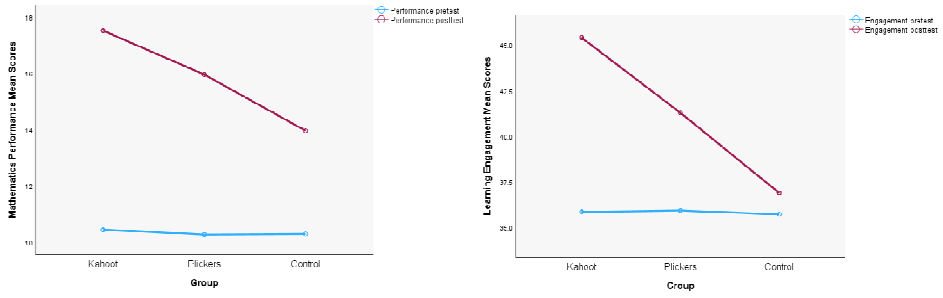
Table 6 Scheffé test scores

Dependent variable	*(I) Group*	*(J) Group*	*Mean difference (I-J)*	*Std. error*	*Sig.*
Performance post-test	Kahoot!	Plickers	1.57	0.706	0.093
		Control	3.56*	0.690	< 0.001
	Plickers	Kahoot!	–1.57	0.706	0.093
		Control	2.00*	0.712	0.024
	Control	Kahoot!	–3.56*	0.690	< 0.001
		Plickers	–2.00*	0.712	0.024
Engagement post-test	Kahoot!	Plickers	4.13*	1.588	0.040
		Control	8.53*	1.553	< 0.001
	Plickers	Kahoot!	–4.13*	1.588	0.040
		Control	4.40*	1.604	0.028
	Control	Kahoot!	–8.53*	1.553	< 0.001
		Plickers	–4.40*	1.604	0.028

Source: Authors

The variance distribution between pre-test and post-test scores of mathematics performance among the groups is illustrated in Figure 5(a). The results highlight differences in post-test scores, with means of $\bar{x}_{post\text{-}testKahoot!} = 17.52$, $\bar{x}_{post\text{-}testplickers} = 15.95$, $\bar{x}_{post\text{-}testcontrol} = 13.96$. The most substantial improvement was observed in the Kahoot! group, where $\Delta\bar{x}_{pre\text{-}test\text{-}post\text{-}testKahoot!} = 7.08$. Overall, the analysis of Figure 5(a) demonstrated that using Kahoot! and Plickers significantly improved students' mathematics performance. On the other hand, the distribution of the variance in the groups in the students learning engagement post-test scores was analysed and presented in Figure 5(b). The results demonstrated that there was an increase in post-test scores in all groups $\bar{x}_{post\text{-}testKahoot!} = 45.40$, $\bar{x}_{post\text{-}testplickers} = 41.27$, $\bar{x}_{post\text{-}testcontrol} = 36.87$. The highest variation was observed in the Kahoot! experiment group $\Delta\bar{x}_{pre\text{-}test\text{-}post\text{-}testKahoot!} = 9.56$. Thus, Figures 5(a) and (b) demonstrated that learning with the Kahoot! and Plickers applications had a significant positive impact on students' mathematics performance and learning engagement when compared to the control group.

Figure 5 (a) distribution of mathematics performance mean scores and (b) learning engagement by experiment groups (see online version for colours)



(a) (b)

Source: Authors

RQ2 What are the differences in learning engagement among students in the three groups (Kahoot!, Plickers, and control group)?

Table 5 indicates a significant effect of the learning methods on learning engagement, $F_{[2,68]} = 15.076$, $p < 0.001$, $\eta_p^2 = 0.307$, confirming that the learning methods (Kahoot!, Plickers, control group) significantly influences learning engagement. The Scheffé method, as detailed in Table 6, further revealed significant differences learning engagement among the learning methods. Specifically, students in the Kahoot! and Plickers classes exhibited significantly higher learning engagement compared to the control class, with p-values of < 0.001 and 0.028, respectively. Additionally, the comparison between Kahoot! and Plickers classes showed a statistically significant difference in learning engagement ($p = 0.040$).

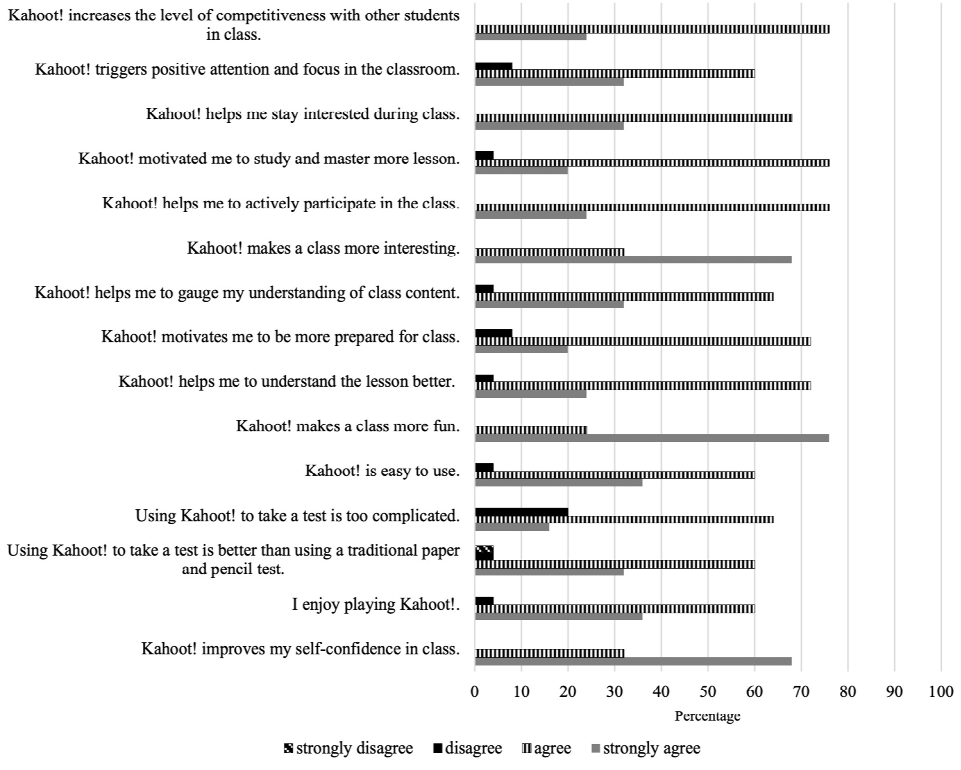
Figure 5(b) illustrates the variance in pre-test and post-test scores of learning engagement across the groups, showing an increase in post-test scores for all groups: $\bar{x}_{post\text{-}testKahoot!} = 45.40$, $\bar{x}_{post\text{-}testplickers} = 41.27$, $\bar{x}_{post\text{-}testcontrol} = 36.87$. The greatest improvement was observed in the Kahoot! group, with $\Delta\bar{x}_{pre\text{-}test\text{-}post\text{-}testKahoot!} = 9.56$. A comprehensive analysis of Figure 5(b) demonstrates that both Kahoot! and Plickers had a significant positive impact on students' learning engagement compared to the control group.

RQ3 How do students' perceptions of learning mathematics differ when using Kahoot! compared to Plickers as SRSs?

The participants were given a questionnaire with a Likert scale, and their responses were used to construct a perception of the intervention (Kahoot! and Plickers) among the experimental students. Figures 7 and 8 illustrate the results.

Over 90% of students have favourable opinions of Kahoot!, as demonstrated in Figure 7. Due to the fact that, in their opinions, more than 90% of students found Kahoot! to be simple to use, pleasant for them to study, and helpful for them to learn the lesson more effectively. The fact that Kahoot! created a fun and engaging learning atmosphere was another thing that all the students noted as helping them stay focused and involved in the lesson. Additionally, Kahoot! also helped students feel more confident in themselves and encouraged them to participate fully in class activities.

Figure 7 Students' perceptions of Kahoot!



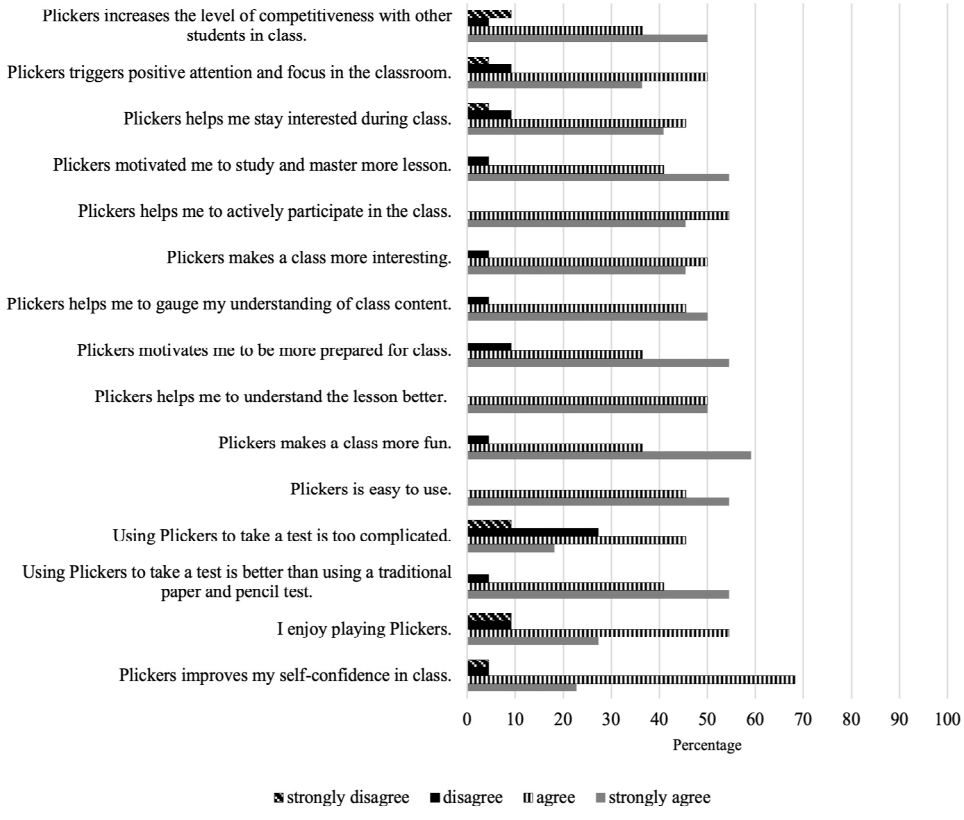
Source: Authors

On the other hand, a small percentage of students found Kahoot! to be difficult to use and distracting, which prevented them from concentrating and enjoying the activity. These students believed that Kahoot! was unable to help them in their understanding of the course material. Moreover, 20% of students stated that Kahoot! was too difficult to use for testing. A small percentage of them preferred taking the test using paper and a pencil.

Furthermore, Figure 8 demonstrates that Plickers was well-liked by students, with almost 90% of them agreeing. More than 90% of students reported using Plickers to make their classes more enjoyable and interesting, to encourage them to prepare more for class, and to assess how much they grasped the course material. Plickers was very simple for all the students to utilise, which inspired them to participate fully in class activities and better comprehend the lesson. In addition, slightly more than 80% of students thought that Plickers may improve their focus and attention, as well as provide them with more self-confidence to compete with their classmates in class activities.

On the other hand, more than 10% of students claimed that Plickers did not help them to stay engaged in the material throughout the lesson since they were unable to stay focused and enjoy the activities. In addition, about 35% of students thought that using Plickers to complete an exam was too difficult, and so only a few of them preferred doing the test with paper and a pencil.

Figure 8 Students' perceptions of Plickers



Source: Authors

Seven students from each experimental class participated in semi-structured interviews to see how they perceived using SRS tools like Kahoot! and Plickers to learn mathematics. The following three questions were asked during the interviews.

Question 1 What did you like about using Kahoot!/Plickers?

Question 2 What were the problems you experienced with Kahoot!/Plickers?

Question 3 Would you like to participate in another Kahoot!/Plickers? Why?

Table 7 summarises the responses from seven students' interviews in Kahoot! class. For Q1, students considered Kahoot! as an accessible learning tool which made the lesson more fun and increased interest in the subject. Using Kahoot! for learning mathematics could increase students' conceptual understanding, speed up their response time, and encourage them to actively take part in the in-class competition. Additionally, when using Kahoot!, the teacher provided students with immediate feedback. For Q2, most students did not have problems while using Kahoot! in class. Meanwhile, the other students complained that there were challenging questions requiring more time than was allocated, and the image on the screen was too small for them to see well. The students also reported that they were unable to log in again after the app crashed. However, students

expressed a willingness to use Kahoot! in their future studies (Q3). Some examples of student statements follow.

> "It is enjoyable, and getting the right answer makes me happy".
>
> "It (Kahoot!) showed the ranking, and the winner received a prize".
>
> "Even though I sometimes fail to win or play it, I still like it and find it exciting".
>
> "Because it's timed, answering the questions requires a lot of quick thinking, which causes mistakes".
>
> "I hope we could always use it (Kahoot!), it's a really good application".

Table 7 Interview results in the Kahoot! class

Question	*Representative comments*	*Frequency of mention*
Q1	User-friendly classroom tool	7
	Brings extra fun to the lesson	7
	Rising enthusiasm for the subject	6
	Students can choose their own Nicknames	2
	It improves comprehension	4
	It helps to think faster	4
	Getting feedback immediately	3
	Positive competition	2
Q2	No problems	5
	Lack of time to answer	4
	There are difficult questions	2
	It is difficult to see the shapes from the screen	1
	When the app crashes, the student cannot sign in again	1
Q3	Yes	7
	No	0

Source: Authors

The responses from the interviews with 7 students in the Plickers class are shown in Table 8. Regarding Q1, most students believed that Plickers was simple to use and made the session more enjoyable. Plickers also could increase students' interest in the subject and improve their conceptual comprehension in mathematics. Plickers helped students answer the questions more quickly and provide immediate feedback as well. For Q2, the findings found that students were using Plickers without experiencing problems. On the other hand, some students complained about using Plickers, citing issues such as difficult questions needing extra time to solve, chaos due to crowded classes, and the additional time required to scan the QR codes. Most students who responded to question 3 indicated that they would be enthusiastic about using Plickers in future studies. Meanwhile, another student preferred to take tests in the future using paper and a pencil. The following are some examples of student statements.

> "I had no problems, it's (Plickers) easy to use".
>
> "Getting a reward for doing well makes me happy".

"If I did not understand the lesson, the teacher would not be judgmental, instead, she would simply repeat it".

"In a crowded class, scanning QR code cards takes a long time. It creates chaos".

"I like taking tests on paper since it is simpler, particularly when faced with challenging questions. It will take time to solve".

Table 8 Interview results in the Plickers class

Question	*Representative comments*	*Frequency of mention*
Q1	User-friendly classroom tool	7
	Brings extra fun to the lesson	7
	Rising enthusiasm for the subject	6
	It improves comprehension	4
	Getting feedback immediately	3
	It helps to think faster	5
Q2	No problems	5
	These are difficult questions	5
	There will be chaos because of the crowded classes	1
	It needs more time for scanning	1
Q3	Yes	6
	No	1

Source: Authors

6 Discussion

The current study examined the impact of using Kahoot! and Plickers as formative assessment tools on student engagement and mathematics performance. The research involved two experimental groups and one control group, with formative assessments conducted after each of four lessons. One experimental group utilised Plickers, while the other used Kahoot! for the assessments. In contrast, the control group relied on traditional question-and-answer methods for formative evaluation.

The results revealed significant differences in students' mathematics performance and learning engagement among the three groups (Kahoot!, Plickers, and the control group). Kahoot!-based and Plickers-based instructional activities had a notable positive impact on student engagement and mathematics performance compared to the control group. However, no significant differences were observed in mathematics performance between the Kahoot! and Plickers groups. These results align with previous research showing that both applications help create interactive and engaging learning environments where students feel motivated in science classes (Eos Trinidad and Radley Ngo, 2019). They also transformed otherwise monotonous questions into dynamic and engaging learning experiences, while promoting meaningful interactions between students and teachers (Eos Trinidad and Radley Ngo, 2019). As Curto Prieto et al. (2019) noted, a positive classroom dynamic, where students can instantaneously view correct answers and engage in game-like strategies, fosters collaborative group discussions and allows students to

share ideas in a relaxed setting. The importance of teacher-student relationships in fostering classroom participation is further highlighted by Li and Xue (2023), who argue that positive teacher behaviours – such as providing guidance, motivation, timely feedback, and support – create an enjoyable and encouraging learning atmosphere that fosters active student engagement. Interactive sessions between teachers and students not only help students evaluate their own strengths and weaknesses but also provide teachers with insights into the depth of students' understanding and areas where further support is needed (Kalleny, 2020). This perspective is aligned with Vygotsky's Zone of Proximal Development (ZPD) theory, which emphasises that learners achieve greater outcomes through collaboration with more proficient peers or adults (Brown, 2014). Vygotsky further argued that social interaction is fundamental to cognitive development, challenging traditional views of fixed developmental stages (Brown, 2014). Student engagement arises from active participation and perceiving mathematics as valuable, applicable, and worthwhile within and beyond the classroom (Attard and Holmes, 2020). When students view the subject as meaningful, they are more likely to immerse themselves in learning activities, showing a strong desire to deepen their understanding (Nepal and Rogerson, 2020). his commitment drives them to invest significant effort and energy, resulting in enhanced academic performance and a more successful and fulfilling learning experience (Fuertes et al., 2023; Li and Xue, 2023).

Furthermore, studies by Chiang (2020), Dellos (2015), and Elmahdi et al. (2018) demonstrated that using Kahoot! and Plickers for formative evaluations fosters an effective learning atmosphere that promotes deeper learning. Both platforms effectively improve students' comprehension, helping them retain learned concepts and apply them to future assignments (Raje and Tamilselvi, 2024). By presenting challenging content in an entertaining manner, these tools enable students to grasp key concepts and better understand the course material (Bicen and Kocakoyun, 2018; Raje and Tamilselvi, 2024). Kahoot!, in particular, has been shown to create enjoyable learning experiences, encourage concept inquiry, and generate a positive atmosphere that motivates active participation and deeper understanding (Bicen and Kocakoyun, 2018; Ebadi et al., 2023; Lebedeva et al., 2023; Raje and Tamilselvi, 2024). As a formative assessment tool, Kahoot! promotes full student engagement, helps identify and fill knowledge gaps, and ensures that misunderstandings are corrected while reviewing learning outcomes (Kalleny, 2020). Similarly, Plickers has been reported to encourage students to prepare for in-class assessments, increasing their engagement and comprehension (Muñoz et al., 2023). Plickers effectively delivers relevant content in an engaging, non-threatening way, giving all students an opportunity to respond (Lebedeva et al., 2023; Rila et al., 2019). Importantly, it ensures equal participation, allowing even shy students to feel free to answer without fear of embarrassment, as Plickers maintains anonymity by not linking responses to student names (Elmahdi et al., 2018; Muñoz et al., 2023; Wood et al., 2021).

However, the findings also revealed that students in the Kahoot! group demonstrated higher learning engagement than those in the Plickers group. This difference can be attributed to Kahoot!'s gamification features, which make learning more enjoyable and interactive compared to Plickers (Veljković Michos, 2017). By focusing on fun-based learning, Kahoot! is designed to foster greater student engagement than typical educational games (Balalle, 2024). The platform provides gamified elements like emotes, points, leaderboards, trophies, and verbal comments like 'good' and 'excellent', which serve as rewards to motivate students to complete assignments and enhance their learning experience (Zhang and Yu, 2021). Bawa (2019) and Janković et al. (2024) also found that

embedding educational material within a quiz-like game framework significantly improves learning by promoting deeper conceptual understanding and enhancing knowledge retention. Moreover, Zhang and Yu (2021) highlighted that an engaging game design not only captures students' interest but also encourages active participation. Gamification in the classroom helps students become more ambitious, putting in greater effort and focus on their studies (Bicen and Kocakoyun, 2018; Lin et al., 2018).

The perception scale and interview results revealed that students had a positive experience using Kahoot! and Plickers as assessment tools. The findings indicate that these tools were well-received and motivated students to actively participate in class activities. Most participants found them easy to use and effective in fostering an enjoyable and engaging learning environment. Additionally, the tools helped students focus and improve their comprehension of the learning content. This aligns with the findings of Raje and Tamilselvi (2024), who highlighted the user-friendly nature of Kahoot! and Plickers, emphasising their ease of navigation and ability to capture students' attention while motivating participation in assessments. Kahoot! and Plickers are consequently effective in gaining attention, evaluating performance, and improving retention and transfer (Çetin and Solmaz, 2020). Additionally, these tools have proven valuable in motivating students to remain engaged during learning activities, possibly helping them identify areas where improvement is needed (Auliya et al., 2023; Lowe et al., 2019; Raje and Tamilselvi, 2024). Consistent use of SRSs, especially when tests are scored, has been shown to improve focus and engagement (Wood et al., 2021). When students find a subject interesting, they are more likely to engage with the material, deepen their understanding, and fill knowledge gaps, ultimately acquiring new skills and competencies (Reeve et al., 2015). For example, students tend to participate more and grasp content more effectively when they find learning mathematics interesting and valuable (Wang, 2012).

Additionally, Sinnivasagam and Hua (2023) and Ahmed et al. (2022) found that students viewed Kahoot! favourably as a tool that increased students' motivation, enjoyment, engagement, and concentration. Kahoot! can be effectively integrated at various lesson stages: at the beginning to assess prior knowledge, in the middle to maintain student attention and break the monotony, or at the end to assess learning progress (Curto Prieto et al., 2019). Supporting this, Janković et al. (2024) found that Kahoot! maintained students' attention levels at an average of 83% during class. Students appreciated Kahoot! to keep them engaged and break the monotony of traditional classroom activities without feeling burdened by additional work (Rajabpour, 2021). When the quiz begins, students noticeably adjust to a more attentive posture and subsequently demonstrate a level of competence when they are held accountable for content from previous lectures, readings, or the class's overall context (Wood et al., 2021). Similarly, Licorish et al. (2018) found that Kahoot! encouraged students to carefully review teaching materials in preparation for quizzes, fostering better comprehension. Complementing this, Auliya et al. (2023) and Muñoz et al. (2023) revealed that Plickers was well received by most students, who appreciated its user-friendly design, engaging learning experience, and effectiveness in enhancing problem-solving skills and subject matter comprehension. Nieto et al. (2022) further emphasised that Plickers streamlined the assessment process, significantly reducing time compared to traditional pencil-and-paper methods. Additionally, Nunes et al. (2023) reported that Plickers encouraged positive student behaviours, such as increased persistence, reduced demotivation, and greater participation in learning activities.

Both Kahoot! and Plickers fostered a positive competitive environment, as corroborated by Raje and Tamilselvi (2024) and Sercanoğlu et al. (2021). Students were motivated to compete with peers, focusing on achieving high scores and improving their understanding (Aldalur et al., 2022). This aligns with Bicen and Kocakoyun (2018), who found that competition enhanced response rates and comprehension of complex topics. This competition acted as a powerful motivator, encouraging students to strive for top performance and stand out in their class (Licorish et al., 2018; Şad and Özer, 2019). Performing well in quizzes boosted students' confidence, particularly when they received recognition and praise from teachers and peers (Dellos, 2015), and the desire to lead class rankings added an element of fun (Göksün and Gürsoy, 2019). The competitive environment and positive feedback provided by tools like Kahoot! and Plickers effectively supported students in identifying their strengths and weaknesses in relation to course material, while fostering a cooperative, healthy competition that encouraged peer connections and contributed to a more enjoyable, supportive learning atmosphere (Raje and Tamilselvi, 2024).

Interviews revealed that immediate feedback was provided by teachers during Kahoot! and Plickers activities played a pivotal role in enhancing learning, aligning with Zhang and Yu's (2021) assertion that feedback is essential in game-based learning. Feedback not only helps identify learning gaps but also increases students' awareness of their learning processes, fostering introspection and self-evaluation (Ramadan Elbaioumi Shaddad and Jember, 2024). By offering accurate evaluations, feedback enables students to learn from their mistakes, adjust their learning strategies, and improve their performance (Rajabpour, 2021; Raje and Tamilselvi, 2024; Zhang and Yu, 2021). Göksün and Gürsoy (2019) highlighted that students' demand for immediate feedback and engaging activities was a key driver for adopting Kahoot! in classrooms. Additionally, feedback from Kahoot! allows teachers to pinpoint specific challenges in the learning process, address them effectively, and play a vital role in initial, formative, and final evaluations (Curto Prieto et al., 2019), ultimately refining teaching strategies to better cater to diverse student needs (Kalleny, 2020).

On the other hand, the use of Kahoot! and Plickers in learning activities presents certain limitations. Students expressed dissatisfaction about being unable to re-enter the game once the Kahoot! application crashed or disconnected in the middle, which led to their distraction and refusal to continue the game, as corroborated by Ebadi et al. (2023). Additionally, the lack of access to mobile devices or internet connectivity demotivated some students, preventing them from participating in Kahoot! activities (Şad and Özer, 2019). Despite these challenges, Kahoot! requires mobile devices and a reliable internet connection to effectively foster interactive teacher-student engagement through competitive, knowledge-based games, making it suitable for classrooms of various sizes (Lin et al., 2018).

Another limitation of Kahoot! is the time pressure it places on students. Some students reported needing more time to complete tasks, often leading to incorrect answers. Similarly, Şad and Özer (2019) noted that the short time limits for answering questions caused students to rush unnecessarily, leading to carelessness and random errors. Chiang (2020) added that this insufficient time allocation could cause frustration and distract students from focusing while giving them too much time could lead to boredom. However, Ebadi et al. (2023) argued that argued that the limited time allocation could be both an advantage and a disadvantage. The time pressure sometimes caused students to stop the quiz, even if they knew the answers, but the speed of the application

could also enhance the quiz's competitive nature, keeping students motivated to study more (Ebadi et al., 2023; Şad and Özer, 2019). Consequently, teachers should carefully adjust the time allocation based on the difficulty of the material, as recommended by Chiang (2020).

Plickers also has its limitations, particularly in the time required to scan QR codes. Rila et al. (2019) found that students sometimes struggled to position their Plickers cards within the teacher's scanning range or experienced dexterity issues, delaying the process, but teachers can mitigate this by moving around the classroom with a mobile device to facilitate scanning and gather responses. In large lecture halls, scanning becomes more difficult due to overlapping or obscured cards (Nasu, 2019). Overcrowded classrooms can also lead to incomplete scans and potential distractions, such as students celebrating correct answers, which could create opportunities for cheating (Öner, 2023). Despite these limitations, Plickers is often considered a more viable option than other tools in classrooms with limited access to digital devices (Çetin and Solmaz, 2020).

Some students also find these tools more challenging than traditional paper-and-pencil tests, especially when faced with difficult questions that require more time to answer. While most students find Kahoot! and Plickers user-friendly, a few still require initial training to become proficient. Chng and Gurvitch (2018) noted that new programs require time and experience to master, but students typically become more comfortable with repeated use. Furthermore, as every student has a unique learning style, it is essential for teachers to adapt their instructional methods to provide personalised learning opportunities for all students (Dellos, 2015). Successful integration of educational technology depends on a customised approach that considers the specific needs of institutions, subjects, learners' levels, and their digital literacy (Balalle, 2024).

7 Implications, limitations, and conclusions

7.1 Implications

The findings have important practical implications for educators, demonstrating that, in contrast to traditional teaching methods, Kahoot! and Plickers significantly improved performance scores and increased student interest and engagement. These applications hold great potential to enhance student engagement and performance, while also enabling teachers to grade assignments more quickly and with less paper. Additionally, both applications automatically store class data, which can be easily accessed, printed, and analysed. The data on students' perceptions of SRSs will help identify the advantages and disadvantages of these tools. The findings highlight the applications' features, creativity, and ability to provide real-time assessment and monitoring of learning activities, addressing students' needs for engaging and relevant knowledge. Furthermore, these tools are cost-effective and economically accessible. Specifically, Plickers does not require students to have internet connectivity or smartphones, as only the teacher needs to use a device, and the cards can be printed from home on standard printer paper. A single device, combined with verbal or paper-delivered questions, is sufficient when classroom technology is limited, eliminating the need for students to have or operate potentially problematic devices. This makes the application a user-friendly and efficient tool, reducing disruptions caused by technological issues in the classroom.

These results provide valuable insights for educators, institutions, and policymakers, highlighting the potential to create classroom environments where students actively engage in learning activities that improve their performance and promote successful learning outcomes in the digital age. The study also contributes to the existing literature on how technology-driven practices mediate student engagement with mathematics and enhance performance. A deeper understanding of how technologies like SRSs can boost student engagement, laying the groundwork for improved academic outcomes, along with an awareness of the subtle effects of tools like Kahoot! and Plickers, can benefit both researchers and practitioners in the field of mathematics education. As technology continues to evolve, ongoing research is crucial to ensure that educators can fully leverage the advantages of technologies to enhance student learning.

However, this study primarily focuses on the SRS tool itself, with insufficient attention to the learning and teaching strategies employed. Future research may benefit from analysing how SRSs can be integrated with specific learning/teaching strategies to improve students' cognitive and affective skills. Additionally, such research might explore the impact of teacher readiness on student participation in technology-based learning and investigate ways to strengthen digital equity, ensuring equal opportunities for all students. Teachers should use various learning strategies with these technologies, especially in active learning activities, while considering the specific needs of institutions, subjects, learners' levels, and their digital literacy, as some schools may have extensive experience with technology in education, while others are just beginning.

7.2 Limitations

There are several limitations to the technology used in this study that should be considered, such as the need for more time to complete questions, as well as the potential lack of devices or an internet connection. The primary limitations of this study were the small sample size and convenience sampling. The small sample size resulted from some students not completing both the pre-test and post-test, with some only completing one of the tests, causing their data to be excluded from the analysis. Future research should allocate additional time for these students to complete the tests. Another limitation was the timing of the research, as students were given access to SRS tools only after two weeks of tutorial lessons, which may not have been sufficient for these tools to significantly affect students' learning engagement. A longer-term evaluation using tools like Plickers, Kahoot!, or other SRSs may be necessary for future studies, as Aibar-Almazán et al. (2024) highlighted that longer periods of use allow for more significant improvement by giving students more time for exploration, reflection, and skill development. However, Pham and Nguyen (2024) noted that excessive use of Kahoot! can lead to student boredom. Therefore, future research could explore the amount of time dedicated to technology-based activities as a critical factor in fostering deeper, more consolidated development. It is also suggested that the optimal duration and frequency of Kahoot! or Plickers use, or even combining both, be explored to maximise educational benefits while avoiding potential adverse effects like cognitive fatigue or loss of interest, as corroborated by Aibar-Almazán et al. (2024).

Furthermore, using technology devices may distract students, as some might use other applications during the activity, so teachers must monitor students closely. In this study, the teacher retained possession of the students' smartphones during the lesson and only distributed them when students needed to take the Kahoot! test, while only the teachers

who required smartphones for scanning student responses were allowed to use them during the Plickers activity.

7.3 Conclusions

This study focused on comparing students' mathematics performance and learning engagement among three groups (Kahoot!, Plickers, and control group) and learning students' perceptions about using SRSs for learning mathematics. Data from the mathematical performance tests, the learning engagement scale, semi-structured interviews, and the perception scale, were gathered. According to the findings, the Kahoot!- and Plickers-based instructional activities positively impacted student learning engagement and mathematical performance. The results further demonstrated that students supported using Plickers and Kahoot! in the classroom as evaluation tools. Regarding student learning engagement, the post hoc analysis revealed that Kahoot! instructional activities were significantly different from those engaged with by the Plickers group. However, students' mathematical performance was poor in the Plickers class and the Kahoot! class did not differ significantly. Furthermore, compared to Plickers and control groups using mean scores, the Kahoot!-based instructional activities proved to have a greater impact on student learning engagement and mathematical performance.

The findings from the semi-structured interviews and perception scale revealed that the students' preferred options for SRS characteristics were its fun and user-friendly features. Thus, students were willing to participate in competitive contexts and have the self-assurance to engage in active learning. Most students could also stay focused and give positive attention in class, which improved their understanding of the lesson material. Therefore, students enjoyed using the SRSs for various other reasons, including encouraging class participation, enhancing learning, and increasing attention.

The authors highlighted several factors that could be considered in future studies. Because Plickers did not require students to have their own devices, it might be a better option for classes with limited access to technology. Plickers allowed students to use cards instead of smartphones or tablets, which reduced the possibility of distraction. However, compared to Kahoot!'s interactive and gamified features, some students might find the card-based interaction less engaging. Kahoot! might be a preferable option in environments where students regularly have access to their mobile devices. Additionally, the activity depended on a consistent internet connection, and connectivity issues might result in the activity ceasing. Consequently, the schools must have the necessary technology to ensure that each student has equitable access to this instructional tool.

Data availability

The datasets generated or/and analysed during current study are available from the corresponding author on reasonable request.

Declarations

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All authors declare that they have no conflicts of interest.

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