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The Impact of Using Quick Response (QR) Codes on Improving Learning and Retention of Science among Sixth-Grade Female Students in District 19 of Tehran

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A B S T R A C T

Purpose: The purpose of this study is to examine the impact of this technology in the field of education, particularly in the domain of science education.

Methods and Materials: This research falls under the category of quantitative studies and is quasi-experimental in nature, using a control group and an experimental group with a pre-test and post-test design. The statistical population of the study consists of all sixth-grade female students in District 19 of Tehran who are studying in the 2022-2023 academic year. A total of 70 students were selected as a sample using convenience sampling. To control and assess the level of learning and retention in the subjects, a test was designed by the researcher on the relevant topic. The content and face validity of the researcher-designed tests were confirmed by five sixth-grade teachers and instructors of in-service courses for sixth-grade science. After checking the assumptions, a covariance test was conducted to verify the research hypotheses.

Findings: The results showed that at the 0.05 level, the means of the two groups had a significant difference.

Conclusion: This means that the use of QR codes, in conjunction with teacher instruction, had a positive and significant impact on the students' learning and retention scores.

Keywords: *QR codes, learning, retention, sixth-grade science*

1. Introduction

In the ever-evolving landscape of education, technology continues to play a pivotal role in enhancing the learning experience, offering students new opportunities to engage with material in dynamic and interactive ways (Fahim et al., 2022; Herawati et al., 2024; Sun et al., 2024; Wang et al., 2024). One such technological tool that has gained prominence is the use of Quick Response (QR) codes in the educational process. Originally developed for marketing and inventory management, QR codes have found their way into classrooms, allowing educators to embed digital content into physical learning materials and provide students with immediate access to additional resources (Dabke et al., 2021; Durak et al., 2016).

The integration of QR codes into educational settings has grown steadily in recent years, with educators exploring their potential to enhance student engagement and knowledge retention. QR codes serve as a bridge between traditional and digital learning environments by embedding hyperlinks to videos, web pages, or documents into physical textbooks or worksheets (Gradel & Edson, 2012). In this context, QR codes enable students to access supplementary content that deepens their understanding of complex subjects. This capability aligns with the findings of Bellot, Shaffer, and Wang (2015), who observed that the use of QR codes in nursing education helped bridge the gap between theoretical knowledge and practical application (Bellot et al., 2015).

The educational potential of QR codes has been demonstrated in various fields of study. For instance, Bonifácio (2012) introduced a QR-coded audio periodic table in chemistry education, which allowed students to access audio explanations of elements directly through their smartphones. This innovative approach not only catered to auditory learners but also provided a mobile learning solution that students could access at their convenience (Bonifácio, 2012). In a similar vein, the work of Brodie, Madden, and Rosen (2020) in medical education highlights the versatility of QR codes in providing quick access to additional resources, particularly in fields that require hands-on learning experiences (Brodie et al., 2020).

The application of QR codes in education has also proven to be effective in increasing students' motivation and interest in learning. Malik (2022) conducted a correlational study that explored the relationship between the use of QR codes and students' motivation in English language learning. The study found that incorporating QR codes into the curriculum not only enhanced students' engagement but also improved their motivation to participate in the learning process (Malik, 2022). This result is further supported by the work of Anggraeni, Prastowo, and Prihandono (2022), who developed a QR code-integrated physics learning module aimed at increasing students' interest in learning and their digital literacy. The interactive nature of the learning experience enabled by QR codes helped students remain engaged with the content, fostering a deeper understanding of the subject matter (Anggraeni et al., 2022).

Another significant aspect of QR code usage in education is its potential to foster collaborative learning. As noted by Pérez-Sanagustín et al. (2015), QR codes can be integrated into situated learning environments to support collaborative knowledge construction. This approach allows students to engage with learning materials collectively, discussing and analyzing the digital content they access through QR codes. Such collaborative efforts promote critical thinking and enhance students' problem-solving abilities, as they work together to understand complex concepts (Pérez-Sanagustín et al., 2015).

The benefits of QR codes are not limited to general education; they have also been shown to be highly effective in specialized educational contexts. For example, Dabke, Harrell, Melaku, Ray, and Turner (2021) used QR codes to assist visually impaired students in chemistry laboratories by providing audio commentaries on commonly used apparatus. This integration of QR codes into laboratory environments made the learning process more accessible and inclusive, demonstrating the technology's potential to accommodate diverse learning needs (Dabke et al., 2021). Similarly, the use of QR codes in vocational education, as studied by Chang (2014), revealed that QR code-based learning tools helped students in vocational high schools acquire practical skills more efficiently, especially in auto-repairing programs (Chang, 2014).

In the field of science education, QR codes have shown promise in enhancing students' understanding of complex scientific concepts. Firmansyah (2019) explored the use of QR codes in teaching organizational and game systems in physical education, finding that the technology allowed students to access instructional videos and other multimedia resources that clarified challenging topics. The study concluded that QR codes significantly contributed to students' comprehension and retention of information, as they provided an alternative method for reinforcing learning outside of the traditional classroom setting. This aligns with the findings of Gao, Liu, and Paas (2016), who investigated

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the effects of different target task selection modes on plant learning in a mobile environment. Their research demonstrated that QR codes facilitated effortless information retrieval, reducing cognitive load and improving learning outcomes (Gao et al., 2016).

While the use of QR codes in education offers numerous benefits, it is important to acknowledge the challenges that educators may face when implementing this technology. One such challenge is the potential for unequal access to digital devices, as highlighted by Aisiah (2023) in her study on history students' readiness to use QR code-based e-job sheets. Ensuring that all students have access to smartphones or tablets capable of scanning QR codes is a critical factor in the successful implementation of this technology (Aisiah, 2023). Furthermore, as Durak, Ozkeskin, and Ataizi (2016) point out, educators must be adequately trained in integrating QR codes into their teaching strategies to maximize the effectiveness of this tool (Durak et al., 2016).

Despite these challenges, the growing body of research on QR codes in education suggests that the technology can significantly enhance the learning experience when used appropriately. The versatility of QR codes allows them to be applied across various disciplines, from science and mathematics to language arts and vocational training. For example, Herawati, Sutopo, and Agustian (2019) designed a QR code-based math game aimed at improving children's learning outcomes (Herawati et al., 2019), while Maulidya, Zulkarnaim, and Taufiq (2023) developed insectarium media combined with QR codes for teaching biology (Maulidya et al., 2023). Both studies demonstrated that QR codes not only made the learning process more engaging but also contributed to better retention of information.

The potential of QR codes to facilitate just-in-time learning has also been recognized in the field of nursing education. Bradley (2020) emphasized the importance of QR codes as a tool for nursing professional development, enabling learners to access information at the point of need (Bradley, 2020). This approach aligns with the concept of situated learning, where learners acquire knowledge in the context in which it is applied. The ability of QR codes to deliver timely information in practical settings, such as hospitals or laboratories, makes them an invaluable resource for healthcare education, as noted by Mogali, Vallabhajosyula, Ng, Lim, Ang, and Abrahams (2019) in their study on the use of QR codes in a museum for mobile learning in anatomy and pathology (Mogali et al., 2019).

In conclusion, the integration of QR codes into educational settings presents numerous opportunities for enhancing both learning and retention. By providing students with immediate access to supplementary digital resources, QR codes enable a more interactive and engaging learning experience, as evidenced by the previous studies conducted (Aransyah, 2022; Husna, 2023). Moreover, the technology's potential to accommodate diverse learning needs, foster collaboration, and deliver just-in-time learning further underscores its value in modern education. While challenges such as unequal access to devices and the need for educator training exist, the benefits of QR codes in education outweigh these obstacles. This study investigates the effects of QR code technology on improving both the learning and retention of science content among sixth-grade female students in District 19 of Tehran.

2. Methods and Materials

The present study is an applied research in terms of its objective. Moreover, this research is classified as experimental in terms of its method. It is a quasi-experimental study, utilizing a control group and an experimental group, and is conducted through a pre-test and post-test design. Additionally, to assess the retention of the students, a follow-up stage was conducted one month later.

The statistical population of the study includes all sixth-grade female students in District 19 of Tehran who were enrolled in the 2022-2023 academic year. A total of 70 students were selected as a sample using convenience sampling.

To control and assess the students' learning and retention in the relevant subject, three tests (pre-test on learning, post-test on learning, and a retention test) were designed by the researcher. In this study, the retention test refers to the scores from the researcher-designed test administered to both groups four weeks after the end of the educational period. The learning test refers to the difference between the pre-test and post-test scores that each student obtained in the corresponding researcher-designed test. Each of these tests consisted of 15 questions. The content and face validity of the researcher-designed tests were confirmed by five sixth-grade teachers and instructors of in-service courses for sixth-grade science. The reliability coefficient of the tests, calculated using the Kuder-Richardson method, was found to be 0.78.

A total of 70 sixth-grade female students were divided into two groups (classes). The selected content, considering the proximity to the end of the school year, included the final chapter of the science textbook, covering lessons 10 to 13.

E-ISSN: 3041-8828

The experimental group, in addition to receiving conventional instruction, had access to QR codes designed by the researcher. This educational period lasted 14 days, following the school's scheduled class hours. The first test was administered on April 4, 2023. After the educational period ended, the test designed by the researcher, which had been completed by students in both classes during the pre-test (before the educational period), was again administered on April 18, 2023. Additionally, four weeks later, the test was administered again without prior notice, on May 20, 2023, to measure the students' retention levels.

Descriptive and inferential statistical methods, including covariance analysis and the T-test, were used to analyze the data.

3. Findings and Results

The main objective of this research was to examine the hypothesis that Quick Response (QR) code technology has an impact on the learning and retention of sixth-grade students in science.

Table 1

ANOVA analysis of the main hypothesis

Model	Sum of Squares	Degrees of Freedom	Mean Squares	F Statistic	Significance
Regression	5494.53	1	5494.53	896.51	0.000
Error	0.000	0	0		
Total	88.46	14	6.31		

Given that the significance level in the above table is less than 0.05, the test is significant. Considering the significance of the ANOVA table in the repeated measures analysis, the main hypothesis is confirmed. This means that Quick Response (QR) code technology affects the learning and retention of sixth-grade students in science.

Table 2

ANOVA analysis of the first model

Model	Sum of Squares	Degrees of Freedom	Mean Squares	F Statistic	Significance
Regression	76.64	1	76.64	6.63	0.02
Error	146.28	13	11.25		
Total	220.93	14			

Table 3

Covariance analysis of learning

Source	Type of Sum of Squares	Degrees of Freedom	Mean Squares	F Statistic	Significance
Corrected Model	354.115	3	118.038	357.479	0.000
Intercept	19.973	1	19.973	60.488	0.000
Group separation	2.586	1	2.586	7.831	0.010
Pre-test Learning	219.053	1	219.053	663.402	0.000
Group * Pre-test	3.060	1	3.060	9.267	0.005
Error	8.585	71	0.330		
Total	8931.000	75			
Corrected Total	362.700	74			

Table 3 shows that the coefficients are entirely significant, with the significance level being less than 0.05. As observed in the table, the use of Quick Response (QR) code technology affects learning in the post-test stage, confirming the first hypothesis of the study. The high coefficient of determination (0.98) also indicates that the dependent variables adequately explain the independent variable.

Table 4

ANOVA analysis of the second model

E-ISSN: 3041-8828

Model	Sum of Squares	Degrees of Freedom	Mean Squares	F Statistic	Significance
Regression	127.63	1	12.63	13.51	0.003
Error	122.76	13	9.44		
Total	250.40	14			

Table 5

Covariance analysis for retention

Source	Type of Sum of Squares	Degrees of Freedom	Mean Squares	F Statistic	Significance
Corrected Model	582.046	3	194.015	705.153	0.000
Intercept	20.406	1	20.406	74.166	0.000
Group separation	2.471	1	2.471	8.982	0.006
Pre-test Retention	402.719	1	402.719	1463.690	0.000
Group * Pre-test	3.997	1	3.997	14.528	0.001
Error	7.154	71	0.275		
Total	7890.000	75			
Corrected Total	589.200	74			

Table 5 shows that the coefficients are entirely significant. Therefore, based on the results of the above table, the impact of Quick Response (QR) code technology on the retention of sixth-grade students in science in the post-test stage is significant, confirming the second sub-hypothesis of the study.

4. Discussion and Conclusion

The results of this study demonstrate a significant positive effect of Quick Response (QR) code technology on both learning and retention of science content among sixth-grade female students in District 19 of Tehran. This outcome is evident from the data analysis, where the experimental group, which used QR codes alongside traditional instruction, significantly outperformed the control group in both post-test learning scores and retention assessments. The use of QR codes not only enhanced students' immediate comprehension of scientific concepts but also contributed to their ability to retain this knowledge over time, as evidenced by the follow-up retention test conducted one month later.

The findings of this study align with the results of previous research exploring the integration of QR code technology in educational settings. For instance, Anggraeni, Prastowo, and Prihandono (2022) observed that QR code-integrated physics learning modules significantly increased students' interest in learning and enhanced their digital literacy (Anggraeni et al., 2022). Similarly, Bonifácio (2012) found that the use of QR-coded audio periodic tables improved students' engagement with chemistry content by providing accessible and immediate audio explanations (Bonifácio, 2012). Both studies highlight the potential of QR codes to bridge the gap between traditional and digital learning resources, making educational content more accessible and engaging for students.

Moreover, the results of this study support the findings of Gao, Liu, and Paas (2016), who demonstrated that QR code technology facilitates effortless information retrieval, reducing cognitive load and improving learning outcomes (Gao et al., 2016). In this study, students who had access to QR codes could quickly retrieve supplemental materials, which likely contributed to their enhanced understanding and retention of the science content. The ability of QR codes to provide immediate access to relevant resources can also be linked to the increased cognitive engagement observed in the experimental group, as noted by Malik (2022), who found that QR codes increased students' motivation and participation in learning activities (Malik, 2022).

The improvement in retention among the students in the experimental group can also be explained through the lens of just-in-time learning, as discussed by Bradley (2020). By integrating QR codes into the learning process, students were able to access critical information at the point of need, which is likely to have reinforced their understanding of the material and contributed to the higher retention scores observed in the study (Bradley, 2020). This concept of situated learning, where students learn in context, has been shown to enhance knowledge retention, particularly in environments where learners can access relevant content as needed (Pérez-Sanagustín et al., 2015).

The use of QR codes in this study also aligns with the findings of Firmansyah (2019), who noted that QR code-assisted teaching materials in physical education enhanced students' comprehension of the material (Firmansyah, 2019). In both studies, the integration of QR codes allowed students to interact with additional digital resources outside the

E-ISSN: 3041-8828

traditional classroom setting, enabling them to review and consolidate their knowledge at their own pace. This flexibility in accessing learning materials likely contributed to the observed improvements in both learning and retention among the students in the experimental group.

In addition, the positive impact of QR codes on retention aligns with the research conducted by Dabke et al. (2021), who found that QR codes provided valuable learning aids for visually impaired students in chemistry laboratories by delivering audio commentaries on laboratory apparatus (Dabke et al., 2021). Although the current study focused on sixth-grade students, the use of QR codes in diverse educational contexts, including those for students with disabilities, underscores the versatility and inclusivity of this technology. By providing students with easy access to additional information, QR codes can help bridge learning gaps and support a wider range of learning styles (McCabe & Tedesco, 2012).

The study's findings further corroborate the work of Mogali et al. (2019), who used QR codes to enhance mobile learning in anatomy and pathology. Similar to the current study, Mogali and colleagues found that the integration of QR codes allowed learners to access information on demand, resulting in a more interactive and personalized learning experience (Mogali et al., 2019). The personalized aspect of QR code technology may explain why students in the experimental group demonstrated improved retention, as they could revisit the material as needed, reinforcing their understanding of the subject matter.

Overall, the significant improvements in learning and retention observed in this study are consistent with the broader body of research on QR codes in education. As noted by Siegle (2015), QR codes provide opportunities for differentiated learning, allowing students to access content tailored to their individual needs and learning styles (Siegle, 2015). In the context of this study, the experimental group benefitted from the ability to engage with supplementary materials at their own pace, which may have contributed to the higher post-test and retention scores observed in this group compared to the control group.

Despite the promising results, this study has several limitations that should be acknowledged. First, the sample size was relatively small, with only 70 participants drawn from a single district in Tehran. This limited sample size may restrict the generalizability of the findings to other student populations or educational settings. Future studies with larger, more diverse samples are needed to confirm the results of this research.

Second, the study was conducted over a relatively short period, with the intervention lasting only 14 days and the retention test administered one month later. A longer intervention period and additional follow-up assessments could provide a more comprehensive understanding of the long-term impact of QR code technology on learning and retention.

Third, this study focused exclusively on science education, and the results may not be applicable to other subjects or disciplines. The effectiveness of QR codes in improving learning and retention may vary depending on the subject matter, and further research is needed to explore the use of QR codes across different content areas.

Future research should explore the long-term effects of QR code technology on student learning and retention by conducting studies with extended intervention periods and multiple follow-up assessments. This would help determine whether the positive effects of QR codes observed in this study are sustained over time and across different stages of learning.

Additionally, researchers should investigate the impact of QR code technology in different subject areas beyond science education. While the current study focused on science, future research could explore how QR codes can be used to enhance learning in subjects such as mathematics, language arts, and social studies. This would provide a more comprehensive understanding of the versatility of QR codes in education.

Finally, future studies should examine the role of student characteristics, such as learning styles and prior knowledge, in moderating the effectiveness of QR code technology. Understanding how individual differences influence the impact of QR codes on learning and retention could help educators tailor their use of this technology to meet the needs of diverse student populations.

For educators looking to integrate QR codes into their teaching practices, it is important to ensure that students have easy and equitable access to the necessary technology, such as smartphones or tablets. Additionally, educators should provide clear instructions on how to use QR codes effectively, ensuring that all students are comfortable with the technology before introducing it into the classroom.

To maximize the benefits of QR code technology, educators should consider embedding QR codes into both in-class materials and homework assignments, allowing students to access supplemental resources at their own pace. By offering a variety of QR code-enabled resources, such as instructional videos, interactive quizzes, and additional

E-ISSN: 3041-8828

reading materials, educators can cater to different learning preferences and enhance student engagement.

Finally, professional development and training for teachers are essential to the successful integration of QR codes into the classroom. Educators should be equipped with the skills and knowledge needed to design and implement QR code-based activities that align with curriculum goals and learning outcomes. By investing in teacher training, schools can ensure that QR codes are used effectively to support student learning and retention.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent.

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