


A QR-Code-Based Mobile Learning System for Science Instruction in Resource-Limited Schools

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Abstract—This study developed and evaluated a QR-Code-Based Mobile Learning System for Science Instruction in Resource-Limited Schools. The system was designed to provide junior high school students with low-cost, mobile-accessible science learning materials through printed QR Code Cards linked to a mobile-responsive digital repository. The developed module set consisted of six curriculum-aligned Life Science topics: Cell: The Basic Unit of Life, Cell Theory, Cell Structure and Functions, Prokaryotic vs. Eukaryotic Cells, Cell Types and Cell Modifications, and Cell Cycle. A developmental, quasi-experimental, and descriptive-evaluative research design was employed. The participants were 80 Grade 9 and Grade 10 students divided into an experimental group using the QR-code-based mobile learning system and a control group using traditional printed flashcards. Results showed that students had moderate overall familiarity with QR codes ($M = 3.52$), highly positive attitudes toward the system ($M = 4.45$), and high usability ratings ($M = 4.38$). The QR Code Cards also received very high ratings in terms of portability, durability, readability, and sustainability ($M = 4.50$). Critically, the experimental group obtained a post-test mean score of 89.15 compared with the control group's mean score of 78.42, yielding a statistically significant difference ($t = 6.24$, $p = .002$, Cohen's $d = 2.49$, 95% CI [7.17, 14.29]), indicating that the QR-code-based mobile learning system significantly improved science achievement by a mean margin of 10.73 points. The findings suggest that QR-code-supported mobile learning can serve as a practical, scalable, and cost-effective instructional innovation for improving science instruction in resource-limited school settings.

Keywords—Academic performance; educational technology; mobile learning; QR code; resource-limited schools; science instruction; usability

I. INTRODUCTION

The increasing demand for technology-supported instruction has encouraged schools to adopt flexible, accessible, and learner-centered approaches that can improve educational delivery across diverse learning environments [1]. In science education, this demand is especially important because students often encounter abstract concepts, microscopic structures, biological processes, and scientific relationships that are difficult to understand through text-based instruction alone [2], [3].

Mobile learning has expanded considerably as a field over the past two decades, with a growing body of evidence documenting its effectiveness in diverse educational contexts [4]. Garzon's review of twenty years of mobile learning in science education found positive effects on student achievement and engagement across multiple grade levels [4]. Traxler argued

that mobile learning is particularly transformative when it addresses access inequalities, enabling students without physical libraries or laboratories to engage meaningfully with instructional content [5]. Unlike traditional computer-based learning, mobile learning supports anytime and anywhere access to educational content, enabling students to continue learning beyond the physical boundaries of the classroom [6], [7]. In resource-constrained schools, mobile-responsive systems offer a cost-effective alternative to expensive computer laboratories or printed reference materials. Reychav, Dunaway, and Kobayashi found that students' technology-fit behavior outside the classroom is influenced by the alignment between the mobile platform and actual learning tasks [6]. When mobile learning systems are designed with curriculum alignment and ease of use as central principles, students are more likely to engage with and benefit from these tools.

The effectiveness of mobile learning has been demonstrated in various fields, particularly in health and professional education, where mobile applications have improved students' knowledge, skills, self-efficacy, clinical reasoning, and competency development [8], [9]. Studies on smartphone-based learning applications have also shown that mobile platforms can enhance active learning, collaborative learning, and independent practice when instructional content is designed for meaningful interaction [10], [11].

Mobile-assisted instruction is especially relevant to Generation Z learners, who are accustomed to smartphone use, rapid digital interaction, multimedia content, and technology-mediated communication [9]. However, students' willingness to use digital learning systems depends not only on access to devices but also on perceived usefulness, perceived ease of use, motivation, and technology acceptance [12], [13].

The Technology Acceptance Model explains that learners are more likely to adopt a technology when they believe it is useful and easy to use [13]. Similarly, studies on digital learning behavior suggest that students' engagement with mobile platforms is influenced by technology fit, learning context, and the extent to which the system supports their actual learning needs [6], [12].

Motivation is also a critical factor in the design of mobile learning systems because students are more likely to engage with learning materials when the system captures attention, establishes relevance, builds confidence, and promotes satisfaction [14]. These motivational principles are important in resource-limited schools, where students may experience reduced access to libraries, laboratories, printed references, and other conventional learning resources [1].

In resource-constrained educational settings, mobile learning provides a cost-effective way to extend access to instructional materials without requiring expensive computer laboratories or advanced infrastructure [4], [5]. For schools with limited physical resources, mobile-responsive learning systems can serve as alternative repositories of multimedia content, allowing students to access videos, diagrams, notes, and interactive activities using available smartphones [6], [15].

Quick Response codes, or QR codes, offer a simple and low-cost mechanism for connecting printed materials to digital learning resources [16]. By scanning a QR code with a smartphone camera, learners can immediately access online or mobile-based content without the need for complex software installation or advanced technical skills [17], [18].

QR codes have been widely applied in education because they can transform static printed materials into interactive learning tools [16], [19]. In medical and healthcare education, QR codes have been used to provide students and practitioners with fast access to learning resources, patient education materials, procedural guides, and interactive academic content [17], [18].

A scoping review of QR code use in healthcare education reported that QR codes are useful for delivering accessible, interactive, and context-specific learning materials [19]. Similarly, broader reviews of QR-code-based learning have shown that QR codes can improve student interaction with content, increase perceived learning effectiveness, and support flexible access to educational resources [20].

In basic education, QR-code-enhanced instructional materials have been used to increase learner engagement by combining physical learning prompts with multimedia content [30]. QR-integrated picture cards and science flashcards have shown potential for improving student participation, conceptual understanding, and retention because they allow students to move from static printed information to richer digital explanations [21], [22].

Flashcards remain a valuable instructional tool because they promote retrieval practice, repetition, and long-term memory reinforcement [23], [24]. Retrieval practice strengthens learning by requiring students to recall information actively rather than merely rereading or reviewing content passively [24].

However, traditional flashcards are limited by their static format and may not sufficiently support complex science concepts that require dynamic visualization, detailed explanation, and multiple forms of representation [2], [3]. Cognitive Load Theory suggests that well-designed instructional materials can support learning by reducing unnecessary cognitive demands and providing learners with clearer representations of difficult concepts [3].

The integration of QR codes into flashcards can address these limitations by combining the memory benefits of retrieval practice with the multimedia advantages of mobile learning [21], [22]. Through this approach, a physical card can function as both a review tool and a digital access point to video lectures, three-dimensional illustrations, lecture notes, discussion prompts, and formative activities.

Mobile video-based learning is particularly useful because videos can support independent learning, repeated viewing, and learner control over pace and sequence [15]. When QR codes are used to provide direct access to short instructional videos and visual learning materials, students can engage with science concepts more flexibly and independently [15], [20].

The use of mobile applications and multimedia systems has also been found to improve learning outcomes when students are provided with opportunities for repeated practice, immediate access to information, and interactive engagement [25], [26]. In nursing and health education, mobile applications, augmented reality tools, simulations, and blended mobile learning models have produced positive effects on students' knowledge, skills, motivation, self-efficacy, and competence [27], [28], [29].

Although many of these studies were conducted in higher education or healthcare education, their findings demonstrate the broader instructional value of mobile learning systems for skills development, knowledge acquisition, and learner engagement [8], [30]. These findings suggest that mobile learning principles can also be applied to junior high school science instruction, especially when the system is designed to be simple, accessible, and aligned with curriculum competencies.

Teacher evaluation and student learning outcomes are also important considerations in technology-enhanced instruction because the success of a learning innovation depends on both instructional design and learner response [31], [32]. Survey-based evaluation can provide useful evidence regarding student attitudes, usability, perceived effectiveness, and acceptance of instructional technology when properly designed and reported [33].

In evaluating educational technology interventions, both quantitative and qualitative evidence can strengthen the interpretation of results [7], [8]. Quantitative data can measure learning outcomes, usability, and acceptance, while qualitative data can explain learner experiences, implementation challenges, and perceived value of the system [34], [35].

Thematic analysis is often used to interpret open-ended responses, interview data, and qualitative feedback in educational research [34], [35]. However, researchers must apply systematic procedures to ensure that themes are credible, consistent, and grounded in participant responses [36], [37].

In K-12 science education specifically, mobile learning has shown significant instructional potential. Studies situated in primary and secondary school settings demonstrate that mobile devices can improve science concept acquisition, support inquiry-based learning, and increase student engagement when instructional content is aligned with curriculum competencies [4], [38], [39]. These findings are especially relevant to resource-limited school contexts, where mobile technology may substitute for libraries, laboratories, and other conventional resources that are unavailable or insufficient.

Despite the growing body of research on mobile learning, QR codes, and technology-enhanced education, there remains a need for more studies focused on low-cost mobile learning systems in basic education science classrooms [4], [20]. Much of the available literature focuses on higher education, nursing education, medical education, or general digital learning

behavior, leaving fewer empirical studies situated in resource-limited junior high school contexts [9], [19].

There is also a need to examine how QR-code-based systems can be designed as practical instructional solutions for schools with limited libraries, laboratories, internet infrastructure, and printed learning materials [1], [5]. In such contexts, QR-code-based mobile learning systems may provide an affordable bridge between physical instructional materials and digital learning resources [15], [16].

The present study responds to this research gap by developing and evaluating a QR-code-supported mobile learning system for junior high school science instruction. The system uses printed QR-code cards linked to a mobile-responsive digital repository containing multimedia science materials aligned with curriculum competencies.

Specifically, the study examines students' familiarity with QR-code technology, the usability and physical characteristics of the QR-code cards, students' attitudes toward the mobile learning system, and the system's effect on science academic performance. By combining instructional material design, mobile learning, QR-code integration, technology acceptance, and academic performance evaluation, the study contributes to the growing literature on low-cost educational technology for resource-limited schools.

II. METHODOLOGY

A. Research Design

This study employed a developmental and quasi-experimental research design to develop, implement, and evaluate a QR-code-based mobile learning system for junior high school science instruction in a resource-limited school setting. The developmental component focused on the design and production of the QR-code cards and the linked mobile-responsive digital learning repository. The quasi-experimental component examined the effectiveness of the system by comparing the academic performance of students exposed to the QR-code-based mobile learning system with that of students taught using traditional printed flashcards. The study also included a descriptive-evaluative component to assess students' familiarity with QR-code technology, their attitudes toward the system, the usability of the mobile learning materials, and the perceived impact of the physical characteristics of the QR-code cards.

B. Research Locale

The study was conducted at San Vicente West Integrated School, Asingan, Pangasinan, Philippines, a school context characterized by limited instructional resources and the absence of a functional library. This setting was selected because it represented the type of resource-limited learning environment for which the QR-code-based mobile learning system was designed. The lack of sufficient physical learning materials created a need for a low-cost, scalable, and mobile-accessible instructional system that could provide students with supplementary science learning resources.

C. Participants and Sampling Technique

This study was conducted at San Vicente West Integrated School, Asingan, Pangasinan, Philippines. A total population sampling technique was employed, involving all grade 9 and grade 10 students enrolled in life science for the SY. 2025-2026, comprising 40 students from each grade level for a total of 80 participants. Within each grade level, students were randomly assigned into two groups of 20: an experimental group, which used the QR-code-based mobile learning system, and a control group, which used traditional printed flashcards. This resulted in a combined experimental group of 40 students (20 from grade 9 and 20 from grade 10) and a combined control group of 40 students (20 from grade 9 and 20 from grade 10), ensuring that both groups were comparable in terms of grade-level composition before the intervention.

D. The QR-Code-Based Mobile Learning System

The instructional intervention developed for this study was a QR-code-based mobile learning system composed of two major components: printed QR-code cards and a mobile-responsive digital learning repository. Each QR-code card was produced using 3×5 -inch laminated cardstock with embedded QR codes linked to specific science learning modules. The system used static QR codes—fixed codes linked to stable, persistent URLs hosted on the digital repository server. Because static QR codes encode the URL directly within the code itself, the physical cards must be reprinted if the linked URL changes. To mitigate this limitation, the researcher ensured that the repository domain and URL structure remained unchanged throughout the study period and documented a link-preservation protocol for future use. Future implementations may consider dynamic QR codes, which allow URL redirection at the database level without requiring the reprinting of physical cards. The six science modules covered were: Cell: The Basic Unit of Life, Cell Theory, Cell Structure and Functions, Prokaryotic vs. Eukaryotic Cells, Cell Types and Cell Modifications, and Cell Cycle.

E. Development Procedure

The development of the QR-code-based mobile learning system followed four phases: needs analysis, content development, system design, and validation. During the needs analysis phase, the researcher identified science topics that students commonly found difficult to understand using printed materials alone. Priority was given to abstract biological concepts that required visual explanation, such as cell structure, cell functions, and the cell cycle. During the content development phase, the researcher prepared and curated multimedia resources aligned with the DepEd MELCs. Each module was designed to include concise explanations, visual materials, and activities that could support independent and classroom-based learning. During the system design phase, QR codes were generated and embedded into the printed cards. Each QR code was linked to a corresponding page in the mobile-responsive digital repository. The physical cards were designed with high-contrast text, visual cues, and module-specific illustrations to support readability, scanning accuracy, and learner engagement. During the validation phase, the QR-code cards, digital learning materials, and research instruments were evaluated by three validators: a content expert, a technical or

ICT expert, and a language and research expert. The validators assessed the materials in terms of content accuracy, technical quality, layout and design, usability, and clarity. Revisions were made based on the validators' comments before the system was implemented in the classroom.

F. Research Instrument

The study used the following instruments:

1) *Science achievement test.* A researcher-developed pre-test and post-test were used to measure students' science achievement before and after the intervention. The test covered the science topics included in the QR-code-based mobile learning system.

2) *QR-Code technology familiarity survey.* This instrument measured students' prior exposure to QR codes in daily life, social media, and academic contexts.

3) *Usability and attitude survey.* This questionnaire assessed students' perceptions of the QR-code-based mobile learning system in terms of ease of use, usefulness, accessibility, engagement, and willingness to use the system for science learning.

4) *Physical characteristics evaluation form.* This instrument measured students' evaluation of the QR-code cards in terms of size, color, texture, durability, portability, readability, and sustainability.

5) *Development difficulty rating form.* This instrument assessed the level of difficulty encountered in developing the QR-code cards and the mobile-responsive digital repository.

All survey instruments used a five-point Likert scale. The instruments were reviewed by experts and pilot-tested before implementation to ensure clarity, relevance, and appropriateness for the target respondents. Fig. 1 shows the system architecture of the QR-Code-Based Mobile Learning System.

student's mobile device, and the printed QR Code Card. These components work together to connect physical instructional materials with digital science learning resources.

The Server Module serves as the core storage and management component of the system. It houses the digital learning repository containing the science instructional materials developed for the six modules included in the study, namely: Cell: The Basic Unit of Life, Cell Theory, Cell Structure and Functions, Prokaryotic vs. Eukaryotic Cells, Cell Types and Cell Modifications, and Cell Cycle. The repository stores the multimedia learning resources linked to each QR code, such as short video lectures, three-dimensional biological illustrations, lecture notes, and interactive discussion prompts. In addition to storing content, the server module manages the links between the QR codes and their corresponding mobile learning pages. This makes the system function as a centralized digital platform that supports the delivery of science content through mobile access.

The Browser represents the web-based interface used to access and manage the digital repository. In the context of the study, this browser component may be used by the teacher or researcher to upload, organize, and update the content for each science module. Because the learning repository is mobile-responsive, the browser-based system allows the instructional content to be delivered in a format that is accessible on standard web-enabled devices without the need for a dedicated application. This component is important because it supports the maintainability and scalability of the system. Once a module page is updated in the repository, the linked QR code can continue to direct students to the revised content without requiring the printed card to be replaced, especially if dynamic QR linking is used.

The Mobile Device refers to the student's smartphone, which functions as the primary access tool for the mobile learning system. Using the phone's built-in camera, the student scans the QR code printed on the card. After scanning, the smartphone opens the linked learning page where the student can view digital science resources and participate in related learning activities. This design is especially appropriate for resource-limited schools because it makes use of widely available student smartphones rather than requiring computer laboratories or specialized learning hardware. The mobile device, therefore, acts as the bridge between the printed card and the digital repository, enabling the system to support both classroom learning and independent study outside school hours.

The QR Code Card is the physical instructional component of the system. Based on the manuscript, each card was produced using 3 × 5-inch laminated 220 gsm cardstock and designed for portability, durability, readability, and repeated classroom use. Each card contains a module-specific QR code that directs students to the corresponding science content in the digital repository. The QR Code Card functions not only as a printed learning aid but also as a physical-digital access point. In this sense, it transforms a conventional flashcard into an interactive learning object by integrating retrieval-based review with mobile multimedia learning.

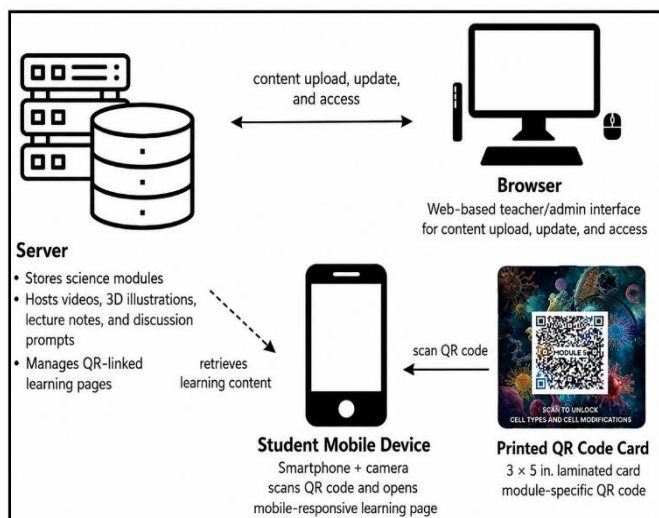


Fig. 1. Architecture of the QR-code-based mobile learning system.

Fig. 1 illustrates the system architecture of the QR-code-based mobile learning system developed for science instruction in a resource-limited school setting. The system architecture is composed of a server module, a browser-based interface, the

G. Data Gathering Procedure

Before data collection, administrative approval was secured from the school principal, and informed consent was obtained from the students and their guardians. The participants were informed about the purpose of the study, the procedures involved, and the confidentiality of their responses. The data gathering procedure began with the administration of the pre-test to both the experimental and control groups. The pre-test established the students' baseline level of science achievement before the instructional intervention. After the pre-test, the experimental group was oriented on how to use the QR-code-based mobile learning system. Students were taught how to scan the QR codes, access the mobile learning repository, navigate the multimedia resources, and use the cards during classroom and independent study activities. The experimental group then used the QR-code-based mobile learning system during science instruction. The students accessed video lectures, biological illustrations, notes, and discussion prompts through the QR-code cards. The control group, on the other hand, received instruction using traditional printed flashcards covering the same science topics. After the intervention period, both groups took the post-test. The experimental group also answered the usability, attitude, QR-code familiarity, and physical characteristics evaluation questionnaires. The collected data were then encoded, tabulated, and analyzed using appropriate statistical tools.

H. Data Analysis

Descriptive statistics were used to summarize the respondents' profiles, QR-code familiarity, usability ratings, attitude toward the system, physical card evaluation, and perceived development difficulty. Frequency counts, percentages, means, standard deviations, and weighted means were computed. The weighted means were interpreted using a five-point verbal interpretation scale. Higher mean scores indicated more positive perceptions of the QR-code-based mobile learning system, greater usability, stronger technology familiarity, or higher perceived impact of the physical characteristics of the cards. To establish baseline equivalence before the intervention, an independent-samples t-test was conducted on the pre-test scores of the experimental and control groups. To determine effectiveness, the post-test scores were compared using an independent-samples t-test. Effect size was calculated using Cohen's d and a 95% confidence interval was computed for the mean difference in post-test scores, enabling practical significance assessment alongside statistical significance. This test determined whether there was a statistically significant difference in science achievement between students who used the QR-code-based mobile learning system and those who used traditional printed flashcards.

I. Proposed Methodological Framework

Fig. 2 presents the methodological framework of the study, organized into three sequential phases. It shows that the research follows three major phases: system development, implementation, data gathering, and data analysis and interpretation.

In Phase 1, the QR-code-based mobile learning system is developed by identifying difficult science topics, preparing multimedia learning content, designing the mobile-responsive

repository and QR code cards, and validating the materials through experts. In Phase 2, the system is implemented with junior high school students. The participants are divided into an experimental group using the QR-code-based mobile learning system and a control group using traditional printed flashcards. Pre-tests, post-tests, and survey instruments are administered to collect data on learning performance, usability, attitude, QR familiarity, and card characteristics. In Phase 3, the collected data are analyzed using descriptive statistics and an independent-samples t-test. The findings are then interpreted to determine whether the QR-code-based mobile learning system is usable, acceptable, and effective in improving science instruction in resource-limited schools.

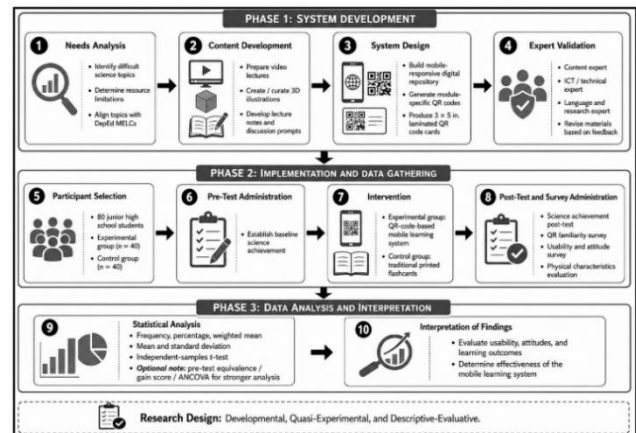


Fig. 2. The proposed methodological framework.

J. Ethical Consideration

The study followed ethical procedures for school-based research. Administrative clearance was obtained before data collection, and informed consent was secured from the participants and their guardians. Participation was voluntary, and students were informed that their responses would be used only for research purposes. No personally identifiable information was included in the analysis or reporting of results. The study also ensured that both the experimental and control groups received science instruction aligned with the same curriculum competencies. The QR-code-based learning materials were used for educational purposes only.

III. RESULTS AND DISCUSSION

A. Profile of the Respondents

The respondents of the study were junior high school students from San Vicente West Integrated School, Asingan, Pangasinan, Philippines. The sample consisted of Grade 9 and Grade 10 students, with a total of 80 participants divided into two groups: the experimental group using the QR-code-based mobile learning system and the control group using traditional printed flashcards. Each group had 40 students. Most of the respondents were between 14 and 16 years old, representing 88% of the sample. The sex distribution was nearly balanced, with 52% female students and 48% male students. Before the intervention, 65% of the students were within the "Satisfactory" range in science, with grades between 75% and 79%. This profile indicates that the participants were appropriate for the intervention because they represented learners who could

benefit from additional instructional support in science. The baseline profile also supports the need for a mobile learning intervention. Since the school setting was resource-limited and lacked a functional library, students required an accessible instructional system that could supplement classroom learning without depending on expensive infrastructure. The use of smartphones and QR-code cards, therefore, provided a practical way to deliver science learning materials through available technology.

B. Pre-Test Equivalence of the Experimental and Control Groups

Before implementing the intervention, an independent-samples t-test was conducted on the pre-test scores of the

experimental and control groups to verify that the two groups were academically equivalent at baseline. Table I presents the pre-test equivalence results.

The pre-test results showed no statistically significant difference between the experimental group ($M = 76.45$, $SD = 4.82$) and the control group ($M = 75.88$, $SD = 5.10$), $t(78) = 0.41$, $p = .684$. The failure to reject the null hypothesis confirms that the two groups were academically equivalent in science before the intervention, thereby strengthening the internal validity of the quasi-experimental design and supporting the interpretability of the post-test comparison.

TABLE I. PRE-TEST EQUIVALENCE OF EXPERIMENTAL AND CONTROL GROUPS

Group	n	Pre-test Mean	SD	t-val	p-val	Decision
Experimental Group: QR-Code-Based Mobile Learning System	40	76.45	4.82	0.41	0.684	Fail to Reject H_0
Control Group: Traditional Printed Flashcards	40	75.88	5.1			

C. Developed QR Code Card Module Set

One of the major outputs of the study was the development of a six-module QR Code Card set for junior high school science instruction. The module set was designed as the physical-digital component of the QR-code-based mobile learning system. Each card contained a QR code that directed students to a mobile-responsive digital repository containing video lectures, three-dimensional biological illustrations, lecture notes, and interactive discussion prompts.

The six QR Code Cards were produced using 3×5 -inch laminated cardstock with a 220 gsm material specification. The cards were designed to be portable, durable, reusable, and suitable for repeated classroom use. The total production cost of the complete six-module set was reported at ₱10,000.00, covering cardstock, printing, lamination, and hosting. Fig. 3 presents the actual QR Code Card module set developed for the study. The cards were designed with science-themed visual backgrounds, embedded QR codes, and module labels to help students identify the topic before scanning. The QR codes served as access points to the digital learning repository, allowing the printed cards to function as interactive learning materials rather than ordinary flashcards.

This QR Code Card of Fig. 3 introduces the cell as the basic structural and functional unit of life. This module provides students with foundational knowledge about why all living organisms are composed of cells and how cells perform essential life processes. Through the QR-linked multimedia materials, students can access visual explanations, lecture notes, and supporting activities that help them understand the cell as the foundation of biological organization.

This QR Code Card of Fig. 4 focuses on the Cell Theory and its historical development. This module guides students in understanding the major postulates of Cell Theory, including the idea that all living things are made of cells, that the cell is the basic unit of life, and that all cells come from pre-existing cells. The QR-linked resources help students connect scientific discoveries with the development of modern biological understanding.



Fig. 3. The cell: The basic unit of life QR code card.



Fig. 4. The cell theory QR code card.

This QR Code Card of Fig. 5 presents the different parts of the cell and their corresponding functions. This module helps students identify major cell structures such as the nucleus, cytoplasm, cell membrane, mitochondria, and other organelles.



Fig. 5. The cell structure and functions QR code card.

The QR-linked videos and three-dimensional illustrations are especially useful in this module because they allow students to visualize cell parts that are normally difficult to observe in a resource-limited classroom.



Fig. 6. The prokaryotic vs. eukaryotic cells QR code card.

This QR Code Card of Fig. 6 helps students distinguish between prokaryotic and eukaryotic cells. This module emphasizes the differences in cell organization, presence or absence of a nucleus, complexity of internal structures, and examples of organisms under each cell type.

Through the QR-linked digital materials, students can compare the two cell types more clearly using diagrams, explanations, and guided activities.

This QR Code Card of Fig. 7 focuses on cell types and cell modifications. This module helps students classify different types of cells and understand how specialized structures support specific cell functions. It is particularly useful for explaining how cells become adapted for particular roles in living organisms. The QR-linked content supports deeper understanding by providing visual examples of specialized cells and their modified structures.

This QR Code Card of Fig. 8 discusses the stages of the cell cycle and their importance in growth, repair, and reproduction.

This module introduces students to the sequence of events involved in cell division, including interphase and the major stages of mitosis. Since the cell cycle is a process-based topic, the QR-linked videos and visual materials help students follow the sequence of changes more easily than printed explanations alone.

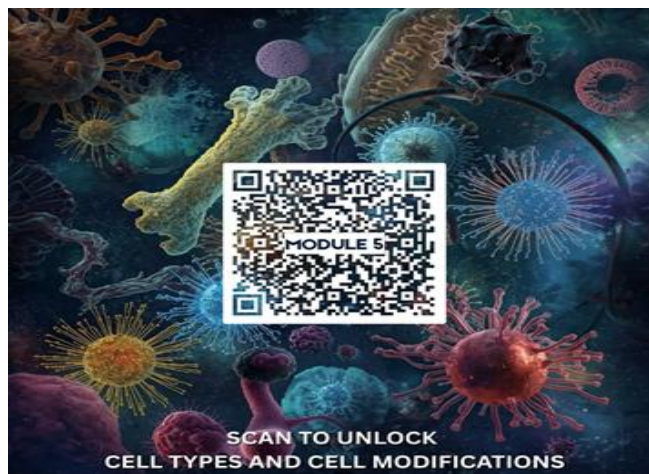


Fig. 7. The cell types and cell modifications QR code card.



Fig. 8. The cell cycle QR code card.

Together, the six QR Code Cards form a structured Life Science learning sequence. The modules begin with the basic concept of the cell, proceed to cell theory and cell structures, compare major cell types, examine cell specialization, and conclude with the cell cycle. This progression supports gradual concept development and allows students to access multimedia learning materials for each topic through a simple smartphone scan.

D. QR Code Card Module Set and Curriculum Alignment

Table II presents the six QR code card module sets and their alignment to the curriculum. The six-module set shows that the QR-code-based mobile learning system was not developed as a general or unstructured digital tool. Instead, it was organized around specific curriculum competencies in junior high school Life Science. This alignment is important because it ensures that the mobile learning system supports required learning outcomes rather than functioning only as a supplementary technology activity.

TABLE II. SIX QR CODE CARD MODULE SET AND CURRICULUM ALIGNMENT

Module	Topic	DepEd MELC Competency	Grade Level
1	Cell: The Basic Unit of Life	Describe the cell as the basic structural and functional unit of life	Grade 9 – Life Science
2	Cell Theory	Explain the postulates of the Cell Theory and their historical development	Grade 9 – Life Science
3	Cell Structure and Functions	Identify the parts of the cell and their corresponding functions	Grade 9 – Life Science
4	Prokaryotic vs. Eukaryotic Cells	Distinguish between prokaryotic and eukaryotic cells	Grade 9 – Life Science
5	Cell Types and Cell Modifications	Classify cells and describe how specialized structures support specific cell functions	Grade 10 – Life Science
6	Cell Cycle	Explain the stages of the cell cycle and their significance to growth and reproduction	Grade 10 – Life Science

The module topics also reflect science concepts that often require visual explanation. Topics such as cell structure, cell functions, prokaryotic and eukaryotic cells, and the cell cycle are difficult to teach using text alone because students need to visualize microscopic structures and biological processes. The integration of QR-linked videos, diagrams, notes, and discussion tasks allowed each printed card to become an access point to richer science learning resources. The physical design of the module set also contributed to its suitability for resource-limited schools. Since the cards were laminated and reusable, the system could be used across multiple lessons and learning activities. The use of dynamic QR codes also allowed the linked content to be updated without reprinting the cards, increasing the maintainability of the instructional system.

E. Students' Familiarity with QR Code Technology

Table III shows the students' familiarity with QR code technology. The students reported high familiarity with QR codes in daily life and social media contexts, but low familiarity with QR codes as part of formal academic learning.

TABLE III. EXTENT OF STUDENT FAMILIARITY WITH QR CODE TECHNOLOGY

Indicator	Weighted Mean	Interpretation
Actual encounter with QR codes in daily life	4.12	High Familiarity
Use of QR codes in social media platforms	4.35	High Familiarity
Awareness of QR codes within the school curriculum	2.1	Low Familiarity
Overall Mean	3.52	Moderate Familiarity

The results indicate that students were already familiar with QR codes as part of everyday digital practices, particularly in social media and commercial transactions. However, their low

familiarity with QR codes in the school curriculum shows that the use of QR codes as an instructional tool was relatively new to them. This finding confirms the need for orientation before implementation. Although the learners were familiar with the scanning process, they had limited experience using QR codes for structured academic learning. This result supports the relevance of the QR-code-based mobile learning system. The system builds on students' existing digital habits and redirects them toward educational purposes. In this way, the intervention transforms a familiar technology into a purposeful learning tool. The moderate overall familiarity also suggests that students were not technologically unprepared, making the system feasible for classroom implementation.

F. Evaluation of the Physical Characteristics of the QR Code Cards

The QR Code Cards were evaluated in terms of size, color, texture, and sustainability. These characteristics were important because the physical card served as the primary access point to the mobile learning system. Table IV shows the impact ratings of QR code card physical characteristics.

TABLE IV. IMPACT RATINGS OF QR CODE CARD PHYSICAL CHARACTERISTICS

Physical Characteristic	Weighted Mean	Interpretation
Size – 3 × 5-inch portability and handling	4.56	Very High Impact
Color – high-contrast design for readability	4.2	High Impact
Texture – laminated durability	4.45	High Impact
Sustainability – re-usability over the full academic year	4.78	Very High Impact
Overall Mean	4.5	Very High Impact

The overall mean of 4.50 indicates that the students evaluated the physical characteristics of the QR Code Cards as having a very high impact. Among the indicators, sustainability received the highest mean of 4.78, followed by size and portability with a mean of 4.56. These results show that the students found the cards durable, reusable, and convenient to handle. The high rating for sustainability is particularly important in a resource-limited school setting. Since the cards were laminated and produced using 220 gsm cardstock, they were able to withstand repeated use during classroom activities. This makes the system practical for schools with limited funds because the cards can be reused over time instead of being replaced frequently. The high rating for size also suggests that the 3 × 5-inch format was appropriate for student use. The card was small enough to be portable but large enough to display the QR code and module information clearly. This supports the idea that the physical design of the learning tool affects its usability and acceptance.

G. Level of Difficulty in Developing the QR-Code-Based Mobile Learning System

The development of the QR-code-based mobile learning system was rated as moderately difficult, with an overall mean of 3.10. The main challenges involved creating a mobile-responsive digital repository, ensuring that the QR codes were scannable across different smartphone models, and preparing

multimedia content aligned with the DepEd Most Essential Learning Competencies. This finding shows that the system was feasible to develop, although it required technical and instructional preparation. The moderate difficulty rating suggests that teachers may be able to replicate the system if they are given proper training in QR code generation, mobile content organization, basic website management, and multimedia curation. The result also highlights the importance of teacher capacity-building. For resource-limited schools to adopt this kind of mobile learning system successfully, teachers need support not only in content development but also in the technical aspects of designing QR-linked learning materials. The inclusion of a teacher's manual or implementation guide may therefore improve the scalability of the system.

H. Students' Attitude Toward and Utilization of the QR-Code-Based Mobile Learning System

The experimental group reported a highly positive attitude toward the QR-code-based mobile learning system, with a mean of 4.45. Students also gave high usability ratings, with a mean of 4.38. These results indicate that the students found the system useful, accessible, and easy to use. Students appreciated the immediacy of access to multimedia learning materials. By scanning the QR Code Cards, they could access video lectures,

biological illustrations, lecture notes, and discussion prompts through their smartphones. This made the learning experience more interactive compared with traditional printed flashcards. The system also functioned as a portable learning resource. Since the students could bring the QR Code Cards home, they were able to review the science modules outside the classroom. This is especially valuable in a school without a functional library because the QR-code-based system provided students with access to supplementary science resources beyond regular classroom instruction. The positive attitude and high usability rating suggest that the system was acceptable to the learners. From a technology acceptance perspective, this means that the students were more likely to use the system because they perceived it as easy to scan, easy to navigate, and helpful for learning science concepts.

I. Comparative Academic Performance of the Experimental and Control Groups

To determine the effectiveness of the QR-code-based mobile learning system, the post-test scores of the experimental and control groups were compared using an independent-samples t-test. Table V shows the independent-samples t-test on post-test academic performance.

TABLE V. INDEPENDENT SAMPLE T-TEST RESULT FOR POST-TEST ACADEMIC PERFORMANCE

Group	n	Post-test Mean	SD	t-val	p-val	Decision
Experimental Group: QR-Code-Based Mobile Learning System	40	89.15	3.45	6.24	0.002	Reject H ₀
Control Group: Traditional Printed Flashcards	40	78.42	5.12			

The results show that the experimental group obtained a higher post-test mean score of 89.15 compared with the control group's mean score of 78.42. The computed t-value of 6.24 and p-value of .002 indicate a statistically significant difference between the two groups. Therefore, the null hypothesis of no significant difference was rejected. This result suggests that students who used the QR-code-based mobile learning system performed significantly better in science than those who used traditional printed flashcards. The mean difference of 10.73 percentage points indicates a substantial improvement in favor of the experimental group. The higher performance of the experimental group may be attributed to the integration of multimedia resources into the learning process. Unlike traditional flashcards, the QR Code Cards provided access to videos, three-dimensional biological illustrations, notes, and discussion activities. These resources likely helped students visualize abstract science concepts more clearly and review the lessons more independently. The result also supports the instructional value of combining physical learning materials with mobile technology. The printed QR Code Card served as a simple and familiar object, while the linked digital repository expanded the learning experience through multimedia content. This combination made the system suitable for a resource-limited school because it did not require expensive technology infrastructure.

J. Discussions

The findings of the study demonstrate that the QR-code-based mobile learning system is a feasible, usable, and effective instructional innovation for science education in a resource-

limited school. The system addressed a specific instructional problem: the lack of sufficient learning resources in a school without a functional library. By connecting printed QR Code Cards to a digital learning repository, the system provided students with access to curriculum-aligned multimedia materials.

The six QR Code Card modules further strengthen the system's instructional value because they were organized around specific Life Science competencies for Grades 9 and 10. The modules covered cell biology topics that require visual and conceptual support, making them appropriate for QR-linked multimedia instruction. Through this structure, the system served not only as a technology innovation but also as a curriculum-aligned instructional intervention.

The pre-test findings established that the experimental and control groups were academically comparable before the implementation of the intervention. Results revealed no statistically significant difference between the experimental group and the control group. This result strengthened the internal validity of the quasi-experimental design because any differences observed in the post-test outcomes could be more confidently attributed to the QR-code-based mobile learning intervention rather than pre-existing academic disparities between the groups.

The students' moderate familiarity with QR code technology shows that the system was appropriate for their digital readiness. Although students were already familiar with QR codes in social media and daily life, they had limited exposure to QR codes as

academic tools. The intervention, therefore, introduced a familiar technology in a new educational context.

The high evaluation of the physical card characteristics confirms that usability is not limited to the digital component of the system. The durability, portability, readability, and reusability of the printed cards contributed to the successful implementation of the intervention. This is particularly important for schools with limited resources because instructional materials must be affordable and long-lasting.

The positive attitude and high usability ratings further indicate that students accepted the QR-code-based mobile learning system. Their favorable response suggests that mobile learning tools are more likely to succeed when they are easy to access, simple to use, and directly connected to classroom learning needs.

Most importantly, the significant difference in post-test performance provides evidence that the system contributed to improved science achievement. The QR-code-based mobile learning system allowed students to access multiple representations of science concepts, including visual, textual, and video-based explanations. These features likely reduced the difficulty of learning abstract topics and supported better understanding.

K. Implication of the Findings

The findings have several implications for science instruction and educational technology implementation. First, QR-code-based mobile learning systems can be used as a practical alternative to expensive digital learning platforms. Since the system only requires printed QR Code Cards, a mobile-responsive repository, and smartphones, it is feasible for schools with limited infrastructure. Second, the system can help compensate for the lack of physical learning resources. In the absence of a functional library, QR Code Cards can serve as portable access points to digital learning materials. Third, the six-module QR Code Card set demonstrates that mobile learning systems should be closely aligned with curriculum competencies. The value of the system does not come from QR codes alone, but from the quality, relevance, and organization of the learning materials connected to each code. Fourth, the study highlights the importance of combining instructional design with technology design. The success of the system depended on the quality of the multimedia content, the alignment with curriculum competencies, the usability of the digital repository, and the physical durability of the printed QR Code Cards. Fifth, the results suggest that teacher training is necessary for wider implementation. Teachers need skills in content curation, QR code generation, mobile-responsive content organization, and evaluation of digital learning materials. Finally, the system may be replicated in other subject areas such as Mathematics, English, and Technology and Livelihood Education. Its low-cost and reusable format makes it suitable for broader school-based adoption.

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

This study concluded that a QR-Code-Based Mobile Learning System for Science Instruction in Resource-Limited

Schools is a practical, acceptable, and effective instructional innovation for junior high school science education. The developed system, composed of six QR Code Card modules linked to mobile-responsive multimedia resources, provided students with accessible learning materials despite the limited physical resources of the school. The findings showed that students were moderately familiar with QR code technology, highly receptive to the use of the system, and positive in their evaluation of the QR Code Cards' usability, portability, durability, and sustainability. The significant difference in post-test performance between the experimental and control groups further indicates that the QR-code-based mobile learning system contributed to improved science achievement. Overall, the system demonstrates how low-cost mobile technology can support science instruction, independent learning, and curriculum-aligned resource delivery in resource-limited school settings.

B. Recommendations

Based on the findings, it is recommended that schools with limited instructional resources adopt the QR-code-based mobile learning system as a supplementary tool for science instruction. The system may help address the lack of physical libraries, laboratories, and printed learning materials by providing students with direct access to digital resources through QR Code Cards. Since the cards are low-cost, portable, reusable, and easy to use, they can serve as practical learning materials for classroom activities, independent study, and home-based review.

It is also recommended that the system be expanded to other science topics and subject areas. Future versions may include additional modules in biology, chemistry, physics, mathematics, English, and other curriculum areas where students need visual, interactive, and multimedia-supported learning materials. Expanding the system will help determine whether the QR-code-based mobile learning approach is effective across different subjects and grade levels.

Teacher training should also be provided to support the effective implementation of the system. Teachers need basic skills in QR code generation, mobile-responsive content preparation, multimedia curation, and integration of QR-linked activities into classroom instruction. With proper training, teachers can develop their own QR Code Cards and adapt the system to the learning needs of their students.

Schools are also encouraged to improve digital access for students. Since the system depends on mobile devices and internet connectivity, administrators may consider providing offline digital repositories, local servers, shared internet access, or downloadable learning materials for students with limited mobile data or unstable internet connections.

These measures will help ensure that all learners can benefit from the mobile learning system regardless of their connectivity situation.

Further research is recommended using a wider sample and a more rigorous research design. Future studies may involve multiple schools, larger groups of learners, and randomized or matched-group designs to improve the generalizability of the findings. Researchers may also include long-term learning

measures such as delayed post-tests, QR scan frequency, student engagement analytics, and retention of science concepts over time.

Finally, the mobile learning repository may be enhanced by adding assessment and feedback features. Future versions of the system may include quizzes, progress tracking, automatic feedback, and teacher monitoring tools. These improvements can make the QR-code-based mobile learning system more interactive, data-driven, and useful for both students and teachers.

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