



Development and Preliminary Evaluation of QR-Linked Visual Cards for Teaching Animal Organ Systems in Sixth-Grade Science

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Abstract

Understanding animal organ systems can be challenging for elementary pupils because internal structures and functions are not directly observable, yet how QR-linked visual resources can complement textbook representations remains insufficiently examined. This study aims to develop and preliminarily evaluate QR-linked visual cards for teaching animal organ systems in sixth-grade science. The study employed a research-and-development approach guided by the ADDIE model, including expert appraisal, a preliminary user trial with 10 pupils, and a one-group pretest–posttest evaluation involving 30 sixth-grade pupils. The developed resource comprised four illustrated cards featuring chickens, ducks, goats, and cows, each linked to a short explanatory video. The findings showed an expert appraisal score of 119 out of 120 possible points (99.2%) across six product-suitability domains and favorable pupil feedback on visual appeal, clarity, and access to supplementary explanations. Normalized-gain results placed 23 pupils (76.7%) in the high-gain category and seven (23.3%) in the moderate-gain category. However, without a comparison group, the observed learning gains cannot be attributed solely to the developed media. This study contributes preliminary evidence about the design and classroom appraisal of QR-linked print–video resources, with implications for multimodal elementary science instruction and more rigorous evaluations.

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1. Introduction

Explaining animal organ systems in elementary science requires more than recognizing anatomical labels: students must connect structures they cannot ordinarily see with processes and functions. Printed diagrams can help locate internal organs, but a still image does not necessarily clarify how those organs work together over time. Analysis of scientific diagrams demonstrates that visual elements communicate different kinds of meaning, including relationships, processes, and temporal sequences (Tang, 2023). Research in primary classrooms likewise shows that scientific understanding is developed through the coordination of images, speech, writing, and other representations (Danielsson



et al., 2023). In the classroom investigated here, preliminary observations and a teacher interview indicated a heavy reliance on textbook images and verbal explanations, alongside difficulties in interpreting internal animal organs. These local observations establish an instructional problem rather than a documented nationwide deficit. They motivate a resource that preserves the accessibility of print while making additional explanations available when needed.

The instructional challenge is representational as well as technological. In elementary science, multiple representations may help learners examine phenomena from complementary perspectives, but their value depends on what students actually do with those representations (Zuhri et al., 2023). Pierson et al. (2023) show the importance of teachers eliciting and coordinating students' diverse ideas and representational practices instead of treating diagrams as self-explanatory. Related research on students' scientific text–picture reading identifies substantial differences in how learners select information and make connections across modes (Jiang & Chiang, 2025). Cheung and Erduran (2025) further demonstrate that drawings and written responses can reveal aspects of scientific understanding that language-only assessments may miss, although their study involved older learners and different science content. Together, these findings suggest that the immediate educational need is not simply more imagery. It is a comprehensible pathway from seeing an anatomical structure to explaining its function and its relationship to other organs.

Two theoretical perspectives specify how such a pathway might be designed. Ainsworth's (2006) Design, Functions, Tasks framework explains that representations can complement one another, constrain misleading interpretations, or encourage deeper understanding when their functions are deliberately differentiated. Multimedia learning theory similarly emphasizes meaningful coordination of visual and verbal information while recognizing limitations in learners' processing capacity (Mayer & Moreno, 2003). Applied to animal anatomy, a printed card might serve as a stable spatial reference, whereas a short video might clarify the sequence or operation of an organ system. This is a proposed division of instructional functions, not a mechanism established by the present data. The importance of support is reinforced by Rexigel et al. (2024), whose STEM meta-analysis found that benefits from combining representations depend on instructional conditions. Cromley and Chen (2025) also identified variation in multimedia learning effects by media, age, outcomes, and design principles. Consequently, the design question is whether the two formats provide intelligible, coordinated explanations rather than merely more content.

Evidence about educational video further clarifies the distinction between access and learning. Park et al. (2022) documented representational strategies used in instructional videos for primary science, including forms of sequencing

and explanation. A comprehensive review by Navarrete et al. (2025) describes substantial variation in video characteristics and the tools used to support video-based learning, cautioning against treating videos as pedagogically uniform. In a meta-analysis, Zhang et al. (2025) found that active strategies accompanying video use were associated with better retention, comprehension, and transfer than passive viewing, although most contributing studies involved adults. Likewise, Thomann and Deutscher (2025) found that the effectiveness of digital-learning prompts varied with their design and context. These studies provide a reason to pair video viewing with targeted classroom questions, but they cannot establish that the videos in this project produced the same effects. A QR code should thus be understood as an access mechanism, not an independent explanation of learning improvement.

Research on QR-supported elementary resources offers a relevant but heterogeneous empirical background. Insani et al. (2023) reported the development of QR Domino cards for animal respiration, while Izzati et al. (2024) investigated a QR-supported board game addressing animal locomotor organs. Other studies developed QR-linked materials for human digestion (Widanti & Fathurrahman, 2024), science and social studies (Istianah & Putra, 2025), and comic-based representations of human organ systems (Anggraini et al., 2026). Elementary science studies have also explored QR-based picture cards (Wulansari & Tyas, 2025), QR-supported scientific-literacy materials (Kartika Sari & Nabilla Qonita, 2024), illustrated media (Supartini et al., 2025), and three-dimensional puzzles (Sholicahah & Setiyawati, 2023). Collectively, these publications show that neither QR codes nor physical–digital combinations are new. However, the products address different topics, employ different forms of representation, and report outcomes using dissimilar appraisal instruments and designs. Their validation percentages should therefore not be used as directly comparable estimates of instructional effectiveness.

Alternative digital formats also require a differentiated assessment. Augmented-reality science resources and their reviews illustrate possibilities for representing concepts that are hard to inspect directly (Andini & Setyasto, 2025; Faria & Miranda, 2024; Rohmani et al., 2024). Further reviews of augmented reality in primary education reach related conclusions while showing variation in settings and outcome measures (Siki & Leba, 2025; Tarmidzi et al., 2025). A network meta-analysis of science learning environments indicates that technologies should be distinguished by their learning affordances and evidence base rather than classified as uniformly beneficial (Koç & Kanadlı, 2025). Studies of digital and interactive elementary science resources also illustrate potentially useful instructional alternatives without testing the particular product examined here (Nasikhah et al., 2022; Saputri et al., 2025). Therefore, the present print–video design should not be characterized as superior to immersive or interactive media. Its practical rationale is narrower: printed images provide an immediately

available reference, while supplementary explanation can be accessed through a familiar scanning function.

Feasibility is especially important because digital augmentation remains dependent on the conditions of use. Research in primary and rural school contexts identifies potential barriers involving teachers' preparation, device availability, infrastructure, and connectivity (Kibirige, 2023; Mustafa et al., 2024; Nettey et al., 2024). A large meta-analysis of mobile learning reports positive average learning outcomes across numerous studies, yet its pooled estimate does not predict the effect of a specific QR-linked card set in a single classroom (Garzón et al., 2025). The cards examined here link to online videos and consequently still require a compatible device and internet access; these conditions were not independently measured in the trial. Therefore, prior research supports investigating both the representational design and its initial classroom usability. It does not justify assuming that convenient access necessarily results in improved conceptual understanding.

Against this background, the research gap concerns the bounded evaluation of a specific instructional configuration, not the invention of QR-enabled learning. The available studies do not directly establish how a compact four-animal set of printed organ-system cards and linked explanatory videos is appraised, initially experienced, and accompanied by assessed learning changes in this classroom context. Accordingly, the study aimed to develop cards depicting chickens, ducks, goats, and cows and to examine three linked questions: how suitable is the resulting product according to expert appraisal, how do students respond in an initial user trial, and what distribution of normalized learning gains is reported after classroom implementation? The ADDIE-guided development was evaluated through expert ratings, feedback from 10 students, and a one-group pretest–posttest trial involving 30 sixth-grade students. The study contributes a transparent design and a preliminary evaluation account of complementary print and video representations. Because no comparison group or process-based measure of representational reasoning was employed, it does not claim to establish a causal effect or a verified learning mechanism.

2. Methods

This study employed a research-and-development approach guided by the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model to develop and preliminarily evaluate QR-linked visual educational cards for teaching animal organ systems in elementary science. The ADDIE model was selected because its systematic stages support the identification of learning needs, the development of instructional materials, and the evaluation of their suitability for classroom use. The study combined expert validation, student-response questionnaires, and a one-group pretest–posttest assessment to

examine three aspects of the developed product: suitability, user acceptance, and learning outcomes. As the classroom assessment did not involve a comparison group, the findings were interpreted as preliminary evidence of learning improvement rather than proof of causal effectiveness.

The analysis stage focused on identifying students' learning needs and the instructional challenges associated with teaching animal organ systems. Data were collected through classroom observations and interviews with the classroom teacher to examine existing instructional resources, students' learning characteristics, and difficulties in understanding the structures and functions of internal animal organs. The information obtained at this stage served as the basis for determining the content, visual features, and digital components of the proposed learning media.

Based on the needs analysis, the design stage involved developing the instructional content and visual layout of the educational cards. Four animals—chickens, ducks, goats, and cows—were selected to represent the organ systems covered in the learning materials. Each card was designed to include illustrations of animal organs, concise explanations, and instructions for accessing supplementary digital content. QR codes were integrated into the cards to provide access to instructional videos hosted on YouTube, each lasting approximately five to seven minutes. This design combined printed visual representations with digital explanations to provide students with complementary ways of accessing information about animal organ structures and functions.

During the development stage, the card designs and accompanying digital resources were produced and subjected to expert validation before classroom implementation. Two experts participated in the appraisal: a sixth-grade classroom teacher with expertise in elementary science and a university lecturer specializing in technology-supported instructional media. The evaluation covered six product-suitability domains: alignment with students' learning needs, clarity of language, alignment with learning objectives, visual appeal and color selection, safety and durability of materials, and ease of use. Each domain consisted of four indicators assessed using a five-point rating scale. The expert assessments provided quantitative ratings and qualitative feedback to evaluate the suitability of the developed materials and to identify aspects requiring refinement.

The implementation stage involved two successive classroom trials. An initial trial with 10 students was conducted to gather preliminary feedback on the educational cards' attractiveness, clarity, and usability. This was followed by a classroom trial involving 30 sixth-grade students, consisting of 16 girls and 14 boys. During the classroom trial, students first completed a pretest to assess their initial understanding of animal organ systems. They then participated in learning activities using the illustrated cards and QR-linked instructional videos during two 35-minute lesson periods. Following the learning activities, students completed a

posttest to assess their understanding of the material after using the developed learning media.

The evaluation stage integrated evidence from expert validation, student responses, and learning assessments to examine the developed product from complementary perspectives. Student perceptions were measured using a 15-item questionnaire with a five-point response scale covering visual attractiveness, ease of use, perceived usefulness, and learning motivation. Learning outcomes were assessed using a 20-item multiple-choice test administered before and after the classroom activities. All research instruments underwent expert judgment before implementation. The reported Cronbach's alpha coefficients were .87 for the student-response questionnaire and .82 for the learning-outcome test, indicating internal consistency above the commonly applied .70 threshold. Together, these instruments provided evidence concerning product suitability, student perceptions, and changes in assessed learning outcomes.

Data were analyzed using descriptive quantitative and qualitative procedures appropriate to the study's developmental objectives. Expert-validation scores were converted to percentages by dividing each score by the maximum possible score and multiplying by 100. Student questionnaire responses were summarized descriptively to describe perceptions of the developed learning media. Changes in learning outcomes were examined using normalized gain (N-gain), categorized as high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), or low ($g < 0.30$). In addition, information obtained from classroom observations, teacher interviews, and expert feedback was summarized descriptively to identify learning needs and product-related considerations. No formal qualitative coding or intercoder reliability procedure was reported. Therefore, the combined analysis provided a preliminary evaluation of the product's suitability, usability, and associated learning outcomes without attributing the observed changes exclusively to the developed media.

3. Results

The findings are presented in five parts: the needs identified during preliminary classroom analysis, the developed card set, expert appraisal of the product, student feedback from the preliminary trial, and normalized learning gains in the classroom trial.

3.1 Limited Variety of Visual Resources for Animal Organ-System Learning

Preliminary classroom observations and teacher interviews identified a limited range of teaching resources for the animal organ-systems topic. Instruction relied primarily on textbook illustrations and teacher explanations, while supplementary digital resources were not routinely available. The needs

assessment also documented students' difficulties in visualizing internal organ structures and connecting these structures to their functions. These observations informed the specification of a resource that combines illustrated print cards with additional explanatory material accessed via QR codes.

3.2 A Four-Card Set Combining Animal Illustrations with Video Access

The development process produced four animal-themed educational cards featuring a chicken, a duck, a cow, and a goat. The illustrations depict selected digestive or respiratory organs, each accompanied by a short explanation. The accompanying QR-code component was designed to provide access to instructional videos of approximately five to seven minutes. Therefore, the product consisted of two connected elements: a physical illustrated card for immediate visual reference and a video resource accessed through a mobile device. Examples of the four illustrated card designs are shown in Fig. 1.

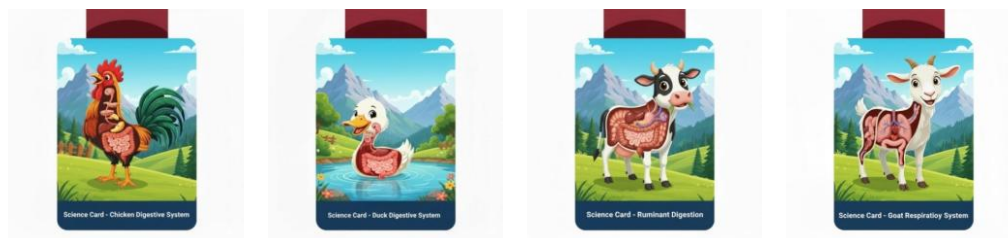


Fig. 1. QR-linked visual card illustrations of animal organ systems (chicken, duck, cow, and goat).

Source: Authors' original educational-card illustrations.

3.3 High Expert Ratings Across Six Product-Suitability Domains

The expert-validation checklist covered six domains, each represented by four indicator ratings on a five-point scale. Five domains received the maximum recorded score of 20 out of 20. Card material safety and durability received 19 out of 20 because one indicator was rated 4 rather than 5. As shown in Table 1, the itemized ratings totaled 119 of 120 possible points (99.2%).

Table 1.

Itemized expert appraisal of the educational cards

Appraisal domain	Indicator ratings	Observed / possible
Alignment with students' needs	5, 5, 5, 5	20 / 20
Comprehensibility of language	5, 5, 5, 5	20 / 20
Alignment with learning objectives	5, 5, 5, 5	20 / 20
Visual appeal of color choices	5, 5, 5, 5	20 / 20
Safety and durability of card materials	5, 5, 4, 5	19 / 20
Ease of use and practicality	5, 5, 5, 5	20 / 20
Total	24 indicator ratings	119 / 120 (99.2%)

Note. Recalculated suitability: $119 \div 120 \times 100 = 99.2\%$; based on the 24 indicator scores shown.

3.4 Favorable Student Feedback in the Preliminary Trial

A preliminary usability trial involved 10 students. Descriptive questionnaire feedback indicated positive responses concerning the attractiveness of the illustrations, the clarity of the explanations, and the ability to access additional information by scanning the QR codes. Students also reported that accessing the linked material helped them explore supplementary information independently. This evidence provides a descriptive account of usability; no item-level response frequencies or composite practicality scores were reported.

3.5 Moderate-to-High Normalized Learning Gains in the Classroom Trial

In the classroom trial, 30 sixth-grade students completed learning assessments before and after using the educational cards. The normalized-gain (N-gain) summary placed 23 students (76.7%) in the high-gain category ($g \geq 0.70$), whereas seven students (23.3%) fell into the moderate-gain category ($0.30 \leq g < 0.70$). No students were classified in the low-gain category ($g < 0.30$). Table 2 presents the category frequencies alongside the prespecified N-gain cutoffs.

Table 2.

Distribution of normalized learning-gain categories (N = 30)

N-gain category	Criterion	Students (n)	Percentage
High	$g \geq 0.70$	23	76.7%
Moderate	$0.30 \leq g < 0.70$	7	23.3%
Low	$g < 0.30$	0	0.0%
Total	—	30	100.0%

Note. Gain categories use the thresholds described in Methods.

4. Discussion

The study provides a basis for interpreting three different kinds of evidence: the representational possibilities of the developed material, its initial acceptance by experts and students, and reported changes in test performance. These forms of evidence are related but not interchangeable. Accordingly, the discussion examines the educational logic of the card–video combination, the limits of product appraisal, the meaning of the observed learning-gain categories, and the study’s bounded contribution to elementary science education.

4.1 Complementary Print and Video Representations Offer Distinct Support for Understanding Animal Organ Systems

The initial needs assessment identified a mismatch between the largely static representations available in the classroom and the conceptual demands of learning about internal animal organs. The developed cards addressed this practical problem by keeping an illustration visible on a physical surface while connecting students to short explanatory videos. The significance of this design

lies less in the QR code itself than in the opportunity to move between complementary representations of structures that cannot normally be observed directly. Ainsworth's (2006) DeFT framework suggests that representations can complement one another, constrain interpretation, and support deeper understanding, provided that learners are able to coordinate the information they convey. In the present product, the printed image could provide a stable spatial reference while the linked video could elaborate on organ functions and processes.

This interpretation is also consistent with the cognitive theory of multimedia learning, which emphasizes active selection, organization, and integration of pictorial and verbal information within limited processing capacity (Mayer & Moreno, 2003). However, the availability of illustrations and videos does not, by itself, establish that students integrated these representations or experienced lower cognitive load. Neither representational coordination nor cognitive load was directly measured. Accordingly, the most defensible interpretation is that the product offers an instructional arrangement compatible with these principles, rather than evidence that a specific cognitive mechanism was demonstrated.

The contrast between a stable diagram and a short video offers a plausible division of instructional labor, but benefits should not be assumed from medium characteristics alone. For instance, Park et al. (2022) found that science instructional videos can employ different representational strategies, while Danielsson et al. (2023) traced how primary students made scientific ideas visible across speech, writing, and drawings. Neither study demonstrates that the particular QR-linked videos developed here prompted equivalent reasoning. Research explicitly comparing representational support and processing also indicates that success depends on what learners notice and integrate, not just the number of formats presented (Jiang & Chiang, 2025; Rexigel et al., 2024). Accordingly, instructional prompts asking students to compare the card illustration with a video sequence would constitute a testable design improvement, rather than a learning outcome established in this trial.

Research on multiple representations in elementary science similarly emphasizes that students benefit when representations are used as resources for explanation and sensemaking, rather than merely displayed as information (Pierson et al., 2023; Zuhri et al., 2023). The present cards are chiefly predesigned materials, whereas Pierson et al. (2023) examined classroom practices that elicited, shared, and refined students' own representations. This distinction identifies an important pedagogical condition for future implementation: teachers may need to ask students to relate a labeled organ in the card to the corresponding explanation in the video, explain an organ's function in their own words, and compare representations across animal species. Such

activities are proposed implications, not procedures or outcomes established by the current data.

4.2 Favorable Initial Appraisals Reflect Perceived Visual Clarity and Ease of Use

The itemized expert ratings indicate favorable judgments across the six assessed suitability domains, with a slightly lower rating for card material safety and durability than for the other domains. These ratings are consistent with the reported preliminary student feedback on visual appeal, clarity, and access to additional information. Together, they support the conclusion that the prototype was considered suitable and acceptable during initial appraisal. They should not, however, be treated as evidence of instructional effectiveness or as a comprehensive psychometric validation of the product.

A related development study by Istianah and Putra (2025) reported favorable expert assessments of QR-code learning cards in elementary science and social studies, while Widanti and Fathurrahman (2024) similarly documented expert acceptance of QR-code-linked digital science materials. The convergence across these studies suggests that combining familiar visual formats with digital access can be workable in particular elementary school settings. Nevertheless, their products, assessment indicators, participants, and study designs differ; consequently, the percentages should not be compared as interchangeable measures of quality. The present prototype received 119 of 120 points (99.2%) on the itemized appraisal; this descriptive value is derived directly from the recorded indicator ratings.

The distinction between favorable reception and dependable classroom use is prominent in prior resource-development reports. Picture-card and QR-linked evaluations by Wulansari and Tyas (2025), Supartini et al. (2025), and Kartika Sari and Nabilla Qonita (2024) employ different forms of expert judgment, respondent appraisal, and learning assessment. These studies support the importance of collecting multiple types of evidence, but do not establish a common numerical benchmark for the present product. Moreover, broader investigations of technology implementation identify unreliable connectivity, limited devices, and the need for teacher support as possible barriers (Kibirige, 2023; Mustafa et al., 2024; Nettey et al., 2024). The present initial responses cannot quantify these barriers, so classroom readiness should be tested by observing actual scanning, video playback, completion of learning tasks, and alternative procedures when digital access fails.

The positive comments from the ten-student preliminary trial are informative but remain descriptive because questionnaire-item distributions, response quotations, and a composite usability estimate were not reported. The participation relationship between the preliminary and classroom samples was not specified. Product acceptability may also vary with teacher support, device

access, scanning reliability, and Internet connectivity, none of which was assessed systematically. QR codes simplify navigation to a resource, but do not eliminate the need for an internet connection to view videos hosted online. A stronger evaluation would therefore document actual task completion in realistic classroom conditions.

4.3 The Absence of a Comparison Group Limits Causal Interpretation of Learning Gains

The classroom trial placed 23 of the 30 students in the high normalized-gain category and the remaining seven in the moderate category. This pattern is compatible with an improvement in assessed performance over the instructional period and merits further investigation. It is also broadly relevant to reports of learning gains in QR-supported elementary science materials. For example, Widanti and Fathurrahman (2024) reported moderate mean N-gain values in their development trials. Their group-level gain estimates and the present study's distribution of individual gain categories, however, are different statistics and cannot be compared numerically as though they measured the same summary outcome.

Several methodological qualifications are essential. The available manuscript does not provide the individual pretest and posttest results, group means, variability estimates, or an independently verifiable mean N-gain. Nor does it report an inferential test of the observed change. The one-group pretest–posttest arrangement lacks a comparison condition and cannot isolate the cards' contribution from teacher explanations, prior knowledge, repeated testing, or other concurrent classroom influences. Therefore, the findings support the narrower statement that moderate-to-high normalized gains were reported after students used the cards; they do not demonstrate a statistically significant effect or establish that the QR-code component caused the observed gains.

It would also be inappropriate to infer the magnitude of a treatment effect from the percentage of students allocated to N-gain categories. Reports based on QR-supported puzzles or other card designs use different scoring and statistical procedures (Izzati et al., 2024; Sholicahah & Setiyawati, 2023). Wider reviews of interactive and mobile learning report positive average outcomes across heterogeneous studies, but their pooled effects cannot be transferred directly to this one-group classroom trial (Garzón et al., 2025; Koç & Kanadlı, 2025; Saputri et al., 2025). This distinction is especially important because changes between repeated assessments can occur in the absence of a specific experimental treatment. Verifiable score-level records, a clearly defined N-gain denominator, and a comparison condition would permit a more informative assessment of the cards' possible contribution.

This distinction also matters theoretically. Improved test performance alone does not show whether learners formed more coherent organ-system

explanations, coordinated visual and verbal information, or transferred their knowledge to unfamiliar animal examples. Those mechanisms require additional evidence, such as explanation tasks, concept maps, classroom interaction records, or delayed transfer assessments. Future studies should report the full score distributions, verify the gain calculations from student-level data, and use a suitable comparison design when testing claims about learning effectiveness.

4.4 Context-Specific Integration of Print and Video Defines the Study's Contribution Beyond QR-Code Technology

The study contributes a context-specific design-and-appraisal account of an illustrated, QR-linked card set for teaching animal organ systems in elementary school. Its contribution is not that QR codes constitute a new educational technology: related card-based and QR-supported resources have already been reported (Istianah & Putra, 2025; Widanti & Fathurrahman, 2024). Rather, the work illustrates how a print-based visual reference and short linked videos were combined for a topic involving otherwise invisible biological structures, then appraised through expert ratings, preliminary student feedback, and classroom learning-gain categories. This contribution is empirical and developmental, not a demonstrated extension of multimedia learning theory.

For classroom practice, the findings justify considering the cards as a promising supplementary resource, provided that teachers verify scientific accuracy, suitability for the intended grade, and the accessibility of the linked content. A practical extension would be to pair the cards with prompts that require students to trace the sequence of organ functions, justify relationships between structures and functions, and compare examples across animals. Such prompts could make representational coordination observable and assessable. Teachers should also plan for shared-device use, captioned video content, accessible print design, and alternative access when connectivity is unreliable. These suggestions follow from the resource's design and relevant literature; they were not directly evaluated in the trial.

Future assessment should align instruments more closely with the intervention's representational claims. Multiple-choice recall questions may capture knowledge of anatomical terminology. However, they provide limited evidence of whether a learner can explain an organ's function, compare respiratory or digestive processes across animals, or detect inconsistencies between visual displays. Recent syntheses of multimedia and science text–picture processing distinguish broad achievement from the specific cognitive activities involved in interpreting multiple representations (Cromley & Chen, 2025; Jiang & Chiang, 2025). Follow-up research could therefore combine validated achievement tests with annotated drawings, short-explanation tasks, delayed-retention measures, and structured classroom observations. A mixed set of indicators would also help establish whether the video component adds

explanatory value beyond a printed illustration. The four-animal structure also offers a possible basis for examining how students transfer functional explanations across biological examples. Chickens and ducks are birds, whereas cows and goats are mammals; comparison tasks could invite pupils to distinguish shared organ functions from species-specific anatomical representations. Students might identify an organ in one card, locate a comparable structure in another, and explain similarities and differences after viewing the linked clips. Such tasks could make the anticipated process of coordinating representations more observable. In the present evaluation, however, the multiple-choice achievement test was not designed to isolate cross-species comparison or transfer. Accordingly, this instructional extension should be treated as a practical proposition for future research rather than an outcome established by the trial.

The findings should be interpreted within substantial methodological boundaries: two expert evaluators, a preliminary trial with ten students, a single-school classroom trial with thirty students, and a one-group pretest–posttest design. Neither individual assessment scores nor independent comparison-group data were available for this analysis. These limitations constrain inferences about causal effectiveness and transferability to other school settings. Research using detailed item-level measurements, delayed assessments, and well-matched comparison groups could establish a stronger evidential basis for the use of QR-linked visual cards.

5. Conclusion

This study focused on the development and preliminary evaluation of visual educational cards with QR codes, designed to teach animal organ systems in elementary science classes. The four-card set combined printed illustrations with short instructional videos to address the shortage of diverse classroom learning resources and the challenges of illustrating internal biological structures. Expert evaluations were generally positive across various product-suitability criteria. Additionally, initial student feedback indicated favorable views of the cards' visual appeal, clarity, and accessibility. In a classroom trial involving 30 students, 23 (76.7%) were categorized as high-normalized-gain, while 7 (23.3%) were categorized as moderate-gain. Overall, these results suggest that the developed resource received positive initial assessments and reported learning gains during implementation. However, it is important to note that these findings do not definitively demonstrate that the cards were the sole reason for the observed improvements.

The key contribution of this study is a concrete example of how to integrate persistent printed visual aids with QR-linked explanatory videos in elementary science education. This approach is supported by initial product evaluations and evidence from classroom trials. The cards could serve as supplementary teaching

tools when paired with effective teacher guidance, opportunities for students to articulate connections between organs and their functions, and reliable access to digital content. Nonetheless, limitations such as the single-school context, a small evaluation sample, the lack of a comparison group, and incomplete reporting of individual learning scores affect the conclusions drawn. Future research should aim to verify the foundational validation and assessment data, delve into students' conceptual explanations and representational reasoning, and assess learning outcomes, accessibility, and retention in more diverse classrooms employing stronger comparative designs.

Declarations

All authors have examined and approved the final version of the manuscript and confirm the absence of competing interests. The research complied with applicable ethical principles, including informed consent and the protection of participant confidentiality. Grammarly was utilized to refine academic language and ensure citation consistency. Artificial intelligence was not employed to generate research data. The authors verified the manuscript and retain full accountability for its accuracy, integrity, and scholarly content.

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