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The Effect of QR Code-Assisted Adventure-Based Learning on Students' Cognitive Learning Outcomes in Atmospheric Science

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Abstract. This study compared changes in Grade X students' cognitive learning outcomes after atmospheric-material instruction using QR code-assisted Adventure-Based Learning (ABL) and conventional instruction. A quasi-experimental nonequivalent pretest–posttest control-group design involved 36 students from SMA Muhammadiyah Al-Amin, Sorong City, selected purposively from two intact classes. Cognitive outcomes were measured using a 20-item multiple-choice test. The available aggregate data were analyzed descriptively through mean scores, raw gain, and normalized gain. The experimental-class mean increased from 57.2 to 85.4 (raw gain = 28.2; N-gain = 0.66), whereas the control-class mean increased from 55.8 to 73.2 (raw gain = 17.4; N-gain = 0.39). Thus, the experimental class achieved a 10.8-point larger raw gain and a 0.27 higher N-gain. These results provide descriptive evidence that integrating QR-linked multimedia and contextual group challenges within ABL may strengthen students' understanding of atmospheric concepts. Inferential conclusions require the reporting of individual scores, standard deviations, and complete statistical-test results

Keywords: adventure-based learning; atmospheric materials; cognitive learning outcomes; mobile learning; QR codes

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Introduction

Atmospheric materials in senior high-school geography include abstract and dynamic concepts such as atmospheric layers, weather elements, air circulation, and climate processes. When these concepts are taught mainly through verbal explanation and static textbooks, students may memorize terminology without adequately connecting it to observable conditions in their environment. Learning activities therefore need to provide contextual experiences, visual representations, and opportunities for students to discuss and apply concepts. Mobile learning provides access to digital resources across locations and allows learning to continue beyond a conventional classroom. A systematic review by (Crompton & Burke, 2018) found that mobile learning is frequently associated with achievement-oriented outcomes and supports learning across formal and informal contexts. Within this environment, Quick Response (QR) codes offer a practical bridge between physical objects and digital information. By scanning a code, students can rapidly access text, diagrams, maps, videos, questions, or other multimedia resources without manually entering a long web address (Durak et al., 2016; Law & So, 2010)

QR codes are particularly relevant for outdoor and location-based learning because a code can be placed at a specific observation point and linked to information that is meaningful at that location. (Rikala & Kankaanranta, 2012) emphasized that QR codes can extend learning beyond the classroom and connect physical learning environments with digital resources. In atmospheric learning, this feature can direct students to weather diagrams, local observations, short explanatory videos, or problem-solving prompts while they are examining real environmental conditions. Adventure-Based Learning (ABL) complements this technological function by organizing learning around sequenced challenges, collaboration, direct experience, and reflection. ABL is learner-centered and uses experiential tasks to promote interpersonal, intrapersonal, and cognitive development (Stuhr & Denny, 2022). Research on adventure education indicates positive contributions to critical thinking, self-efficacy, cooperation, and broader developmental outcomes, although effects depend on program quality and implementation context (Ghani et al., 2025; Webber et al., 2025). When QR codes are embedded in ABL stations, students can move through authentic settings, obtain targeted information, discuss evidence, and solve tasks collaboratively.

Previous studies have reported positive learning outcomes from QR-supported instruction. QR code-enhanced materials have improved cognitive and skill outcomes (Al-Sababha, 2024), supported positive attitudes and sustained cognitive achievement in cooperative learning (Rakha, 2025), and helped connect printed materials with interactive digital content (Uçak, 2019; Widyasari et al., 2019). However, research that specifically combines QR codes, ABL, and atmospheric materials at the senior high-school level remains limited. The present study therefore aimed to compare changes in cognitive learning outcomes between students who received QR code-assisted ABL and students who received conventional instruction. The working hypothesis was that the QR code-assisted ABL group would show a greater improvement in cognitive scores.

Theoretical Framework

Constructivist Learning Theory

Constructivist learning theory views students as active builders of knowledge rather than passive recipients of information. New understanding is formed when learners connect prior knowledge with experience, social interaction, and reflection. (Vygotsky & Luria, 1978) emphasized the social nature of learning and the importance of guidance and collaboration in helping students complete tasks that they could not yet perform independently. In this study, constructivism provides the principal explanation for why contextual exploration, peer discussion, and teacher scaffolding may improve students' understanding of atmospheric phenomena. QR code-assisted learning is consistent with constructivism when students do more than scan and receive information. Students must interpret QR-linked resources, compare them with field observations, discuss alternative explanations, and use the information to complete an authentic task. The value of the technology therefore depends on the learning activity surrounding it. A QR code used only to deliver a digital text may reproduce teacher-centered instruction, whereas a QR code embedded in a collaborative inquiry task can support active knowledge construction.

Adventure-Based Learning

ABL is an experiential pedagogical approach that uses sequenced challenges, teamwork, communication, problem-solving, and structured reflection. The approach is not limited to physical adventure; its educational purpose lies in placing learners in meaningful situations that require decisions and shared responsibility. (Stuhr & Denny, 2022) describe ABL as a model that combines cooperative activities with reflection to support the transfer of learning. (Williams & Wainwright, 2016) similarly argue that adventure education requires an explicit pedagogical model so that challenge and experience remain connected to intended learning outcomes. In the present context, ABL provides the instructional structure through which students explore atmospheric concepts. Learning stations and group challenges allow students to observe environmental conditions, communicate findings, and connect abstract concepts to actual phenomena. Reflection is essential because it helps students articulate what they observed, explain why it occurred, and relate the experience to scientific concepts. This design is expected to strengthen conceptual understanding rather than merely increase activity.

Mobile Learning

Mobile learning refers to learning supported by portable digital devices across different contexts and locations. Its central characteristics include mobility, flexibility, connectivity, and access to learning resources at the moment they are needed. (Crompton & Burke, 2018) show that mobile learning can support achievement, collaboration, and learning outside fixed classroom boundaries. In this study, students' smartphones functioned as access devices that connected outdoor learning stations with digital atmospheric resources.

QR Codes as Learning Media

A QR code is a two-dimensional code that can store or direct users to digital information. As an instructional medium, it can connect printed materials, physical locations, and real objects with multimedia resources. (Law & So, 2010) identify ease of access and compatibility with mobile devices as important educational features. (Durak et al., 2016) further show that QR codes can support communication and mobile learning when they are incorporated into a purposeful lesson design. The pedagogical function of QR codes in this study was to provide immediate access to resources related to each learning task. Such resources may include diagrams of atmospheric layers, weather maps, explanatory videos, short readings, and problem prompts. This reduces the time needed to search for information and helps students focus on interpreting evidence. QR codes also allow the same physical learning environment to contain differentiated or multimodal resources, which may support students with different learning needs.

Cognitive Learning Outcomes

Cognitive learning outcomes refer to changes in students' knowledge and thinking following instruction. The revised taxonomy of (Anderson et al., 2023) organizes cognitive processes from remembering and understanding to applying, analyzing, evaluating, and creating. The learning-outcome test in this study focused on students' knowledge and understanding of atmospheric materials and their ability to apply concepts to questions. The theoretical relationship among the study variables is that constructivist ABL creates authentic and collaborative learning experiences, mobile devices provide flexible access, and QR codes connect each experience with relevant digital information. Together, these processes are expected to support stronger cognitive outcomes.

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Methodology

Research Design

This study used a quasi-experimental nonequivalent pretest–posttest control-group design. Two intact Grade X classes were involved. Both groups completed a pretest before instruction and a posttest after instruction. The experimental class received QR code-assisted ABL, whereas the control class received conventional instruction on the same atmospheric content. The design was selected because reorganizing students into newly randomized groups was not feasible within the normal school schedule.

Participants and Sampling

The population consisted of Grade X students at SMA Muhammadiyah Al-Amin, Sorong City, who studied geography during the 2025/2026 academic year. The sample comprised 36 students from two intact classes. Purposive sampling was used consistently because the classes were selected according to their relevance and feasibility for the intervention: they studied the same curriculum and atmospheric unit, had relatively comparable academic backgrounds, followed the same school timetable, and were available to participate in the complete learning sequence. Students remained in their existing classes to minimize disruption to school activities.

Learning Intervention

The experimental learning sequence combined ABL with QR-linked learning stations. Students worked in small groups and moved through contextual tasks related to atmospheric phenomena. At each station, students scanned a QR code to access relevant multimedia information or instructions, observed the surrounding environment or provided stimulus material, discussed the evidence, and recorded a group response. The teacher facilitated safety, time management, questioning, and reflection. The control class studied the same content through conventional teacher explanation, textbook-based materials, and classroom exercises. Both groups completed the same cognitive pretest and posttest.

Research Instrument

Cognitive learning outcomes were measured with a 20-item multiple-choice test on atmospheric materials. Each item contained four response options and one correct answer. The items were prepared according to the learning objectives and cognitive indicators for Grade X atmospheric content. Content validity was examined through expert judgment by a geography teacher and academic supervisor. Empirical item validity was evaluated using Pearson's product–moment correlation, and internal consistency was evaluated using Cronbach's alpha. The final manuscript should report the number of valid items, the item-correlation range, and the obtained reliability coefficient rather than only the acceptance criterion.

Data Analysis

Descriptive analysis included the mean, standard deviation, minimum, maximum, raw gain, and normalized gain. Normalized gain was calculated as (posttest mean − pretest mean)/(maximum score − pretest mean) and interpreted as high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), or low ($g < 0.30$), following (Hake, 1998). For a complete inferential analysis, normality should be examined using the Shapiro–Wilk test and variance homogeneity using Levene's test. If assumptions are met, group differences may be tested using analysis of covariance with posttest as the outcome and pretest as the covariate, or an independent-samples t-test on gain scores. Exact p values, 95% confidence intervals, and an effect size such as Cohen's d should be reported.

Results and Discussion

Results

Table 1 presents the aggregate pretest and posttest scores available in the manuscript. The experimental class increased from 57.2 to 85.4, producing a raw gain of 28.2 points. The control class increased from 55.8 to 73.2, producing a raw gain of 17.4 points. The difference between the groups' raw gains was therefore 10.8 points in favor of the experimental class.

Table 1. Descriptive Changes in Cognitive Learning Outcomes

Group	Pretest Mean	Posttest Mean	Raw Gain	N-Gain	Category
Experimental	57.2	85.4	28.2	0.66	Moderate
Control	55.8	73.2	17.4	0.39	Moderate

Note. N-gain calculations assume a maximum score of 100. Inferential statistics require individual-level data.

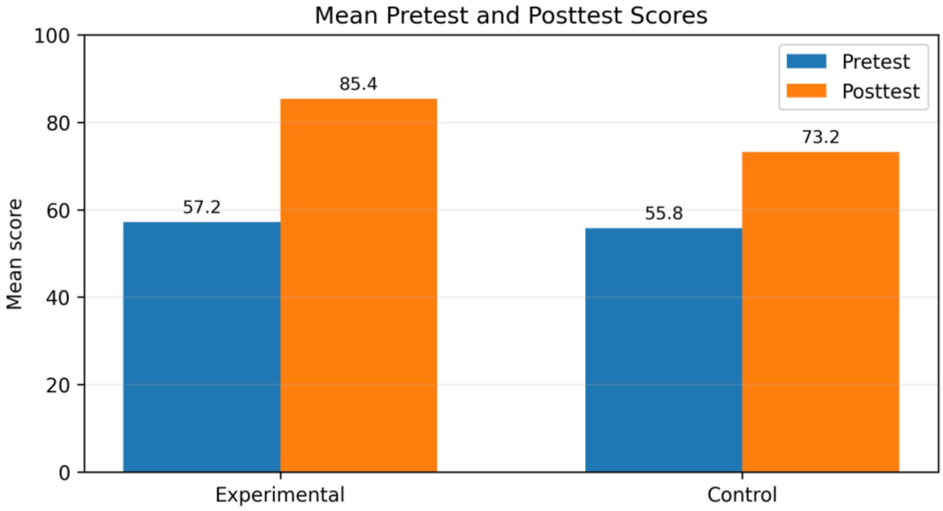

Figure 1. Mean pretest and posttest scores in the experimental and control classes.

The experimental-class N-gain was 0.66, whereas the control-class N-gain was 0.39. Both values fall within the moderate category, but the experimental group's normalized gain was 0.27 higher. Descriptively, the result indicates a larger improvement following QR code-assisted ABL. However, statistical significance and the magnitude of the effect cannot be established from group means alone. Therefore, the revised manuscript avoids unsupported statements that the difference was statistically significant.

Discussion

The larger descriptive gain in the experimental class is consistent with the theoretical expectation that students learn more meaningfully when they actively connect information with experience. From a constructivist perspective, the intervention did not position students only as recipients of atmospheric explanations. Students encountered contextual tasks, accessed relevant information, discussed interpretations with peers, and used the information to solve problems. These processes support the social construction of knowledge and guided learning described by (Vygotsky & Luria, 1978). ABL supplied the experiential and collaborative structure of the intervention. Students' movement through learning stations, group decision-making, and reflection may have made abstract atmospheric concepts more concrete. This interpretation is aligned with ABL literature emphasizing sequenced challenges, cooperation, and reflection (Stuhr & Denny, 2022; Sutherland & Stuhr, 2014). It is also consistent with the broader systematic-review evidence that adventure education can support cognitive and social development when learning experiences are intentionally designed (Ghani et al., 2025).

QR codes likely contributed by providing information at the point of need. Instead of separating field observation from classroom explanation, QR-linked resources allowed students to access diagrams, videos, or questions while completing the relevant task. This immediate connection can reduce navigation time and strengthen the relationship between a physical phenomenon and its conceptual explanation. (Durak et al., 2016; Law & So, 2010; Rikala & Kankaanranta, 2012) similarly describe QR codes as a means of connecting mobile devices, physical contexts, and digital learning resources. The findings also correspond with empirical research on QR-supported learning. (Al-Sababha, 2024) found that QR-enhanced instructional materials improved cognitive and skill outcomes, while (Rakha, 2025) reported substantial cognitive improvement and positive attitudes when QR codes were embedded in cooperative learning. (Uçak, 2019) found that QR codes enriched science teaching materials, and (Widyasari et al., 2019) showed their usefulness in linking printed learning content to mobile activities. These studies support the interpretation that the benefits arise not from the code itself, but from the accessible, interactive, and learner-centered resources to which the code provides entry.

A further explanation concerns multimedia representation. Atmospheric processes are difficult to understand because they involve invisible movements, spatial relationships, and changes over time. QR-linked diagrams, animations, and short videos can provide complementary representations that help students visualize these processes. When these representations are integrated with direct observation and group explanation, they can strengthen comprehension and application rather than simple memorization. QR codes therefore function as an instructional medium within a broader pedagogical design, not as an independent teaching method.

Pedagogical Implications

Teachers can use QR code-assisted ABL to organize atmospheric learning around a small number of well-designed outdoor or school-environment stations. Each code should have a clear instructional purpose, such as presenting a visualization, providing data, posing a question, or directing students to compare observations. Tasks should require students to explain evidence and make decisions collaboratively. A concluding reflection should connect field experiences to formal geographic concepts. Schools should also ensure device availability, Internet access or offline alternatives, safe movement routes, and teacher preparation for managing both technology and outdoor group work.

Limitations

The study involved a small sample from one school and used intact classes without individual random assignment, which limits generalization and causal certainty. The supplied manuscript did not include individual scores, standard deviations, instrument coefficients, or complete inferential-test outputs; consequently, the current revision can only interpret descriptive changes. The study also did not report a delayed retention test, and the contribution of individual intervention components—ABL, collaboration, outdoor context, and QR-linked media—could not be separated. Future research should use a larger multisite sample, report complete statistical results, include fidelity measures and retention testing, and compare QR-assisted ABL with ABL delivered without QR codes.

Conclusion

The study objective was to compare cognitive learning-outcome changes between QR code-assisted ABL and conventional instruction on atmospheric materials. Based on the available aggregate data, the experimental-class mean increased by 28.2 points with an N-gain of 0.66, whereas the control-class mean increased by 17.4 points with an N-gain of 0.39. The experimental class therefore showed a larger descriptive improvement. The findings suggest that combining contextual adventure-based tasks with immediate access to QR-linked digital resources can support students' understanding of atmospheric concepts. A definitive claim of statistical effectiveness should be made only after the authors report standard deviations and complete inferential-test results from the individual dataset.

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