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Development of Katar-Bio: Smart Card-Based Interactive Media to Improve of Second-Grade XI Students' Understanding and Motivation in Respiratory System Topics

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Abstract

Background: *The issue of low conceptual understanding and learning motivation among students in the respiratory system topic highlights the need for more interactive and engaging learning media innovations. This study aims to develop an interactive learning medium based on biology smart cards (Katar-Bio) to enhance Grade XI students' conceptual understanding and learning motivation.* **Methodology:** *The study employs the 4-D development model (Define, Design, Develop, and Disseminate), involving 30 students from class XI MIA[1] at SMA Swasta Budi Agung Marelan. The research instruments include expert validation sheets, student and teacher response questionnaires, a learning motivation scale, as well as pretest and posttest items.* **Findings:** *The development stages consist of needs analysis, media design, expert validation, practicality testing, and effectiveness evaluation. Expert validation results yielded feasibility scores of 95% for media and 79% for content. The practicality level was categorized as very high, with student responses at 92% and teacher responses at 96%. The effectiveness of the media was measured using the N-Gain formula, resulting in a score of 0.80 (high category), indicating a significant improvement in conceptual understanding. Additionally, there was a 31.45% increase in students' learning motivation after using the media. These findings demonstrate that Katar-Bio media positively contributes to the learning process, both academically and motivationally. The media is also equipped with QR codes linked to instructional videos and online quizzes to enhance interactivity.* **Contribution:** *The academic implications of this study suggest that Katar-Bio can be widely implemented and adapted for other biology topics. Scientifically, this medium integrates digital technology through QR codes into smart cards, making it an innovative learning approach that has not been widely applied in teaching the respiratory system topic.*

Keywords: *Biology Smart Card; Katar-Bio; Learning Motivation; Interactive Learning; Respiratory System*

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INTRODUCTION

Education plays a vital role in shaping human resources to be excellent, globally competitive, and possess noble character (Emawati, 2021). However, efforts to improve the quality of education in Indonesia still face various challenges, one of which lies in the quality of classroom instruction, which is highly influenced by the competence of educators as well as the selection of appropriate teaching methods and media (Nainggolan et al., 2024). An effective learning process does not merely transfer knowledge but also fosters the development of critical thinking skills, creativity, and the cultivation of students' character (Sutikno et al., 2022).

In this context, teachers as facilitators are required to create an active and enjoyable learning environment and utilize instructional media that align with students' needs (Inu et al., 2023). Innovative instructional media are believed to enhance learning motivation and assist students in understanding abstract concepts that are difficult to grasp through conventional methods (Afnita et al., 2023).

One of the subjects with a high level of complexity is Biology, particularly the topic of the human respiratory system. This topic involves physiological processes that cannot be directly observed, making it challenging for students to develop a clear conceptual understanding (Mufidah & Habibi, 2022). Observations conducted at Budi Agung Marelan Private Senior High School indicate that biology instruction still largely relies on lecture-based methods and limited use of PowerPoint media. As a result, students' conceptual understanding and learning motivation particularly in the topic of the respiratory system remain low. Based on teacher observations, most students in class XI MIA 1 have not met the Minimum Mastery Criterion (a.k.a KKM) of 75. According to the summary of daily test scores, more than half of the students scored below the KKM on the respiratory system material. This suggests that the current instructional media and strategies have not been optimal in supporting students' conceptual understanding and learning motivation.

Innovative and interactive learning media are needed to address these challenges to enhance student engagement. One alternative that can be utilized is the biology smart card, a print-based medium that presents essential information visually and is equipped with QR codes that direct students to additional online materials, such as instructional videos or interactive quizzes (Tomi & Jamilah, 2020). Integrating QR codes into print-based media enables learning to become more flexible and engaging, while also enhancing the connectivity between offline and online learning experiences (Smith et al., 2018). International studies have shown that using QR code technology in education has proven effective in enhancing student engagement and conceptual understanding across various educational contexts (Bahtiar & Surjono, 2020).

Previous studies have developed smart card media for various educational purposes, such as enhancing students' habits of mind (Emawati, 2021), character education reinforcement (Damayanti & Jayanti, 2024) and improving students' learning outcomes in the topics of ecosystems and cells (Miskiyah & Safitri, 2023; Tomi & Jamilah, 2020). However, to date, no studies have been found that specifically develop QR code-based smart card media designed for the topic of the respiratory system. In fact, the respiratory system is a biology topic requiring deep

conceptual understanding and often poses difficulties for students. Therefore, there is a need for innovative, interactive, and contextual learning media to enhance students' understanding and learning motivation.

Based on these considerations, this study aims to develop an interactive learning medium based on biology smart cards (Katar-Bio) that is valid, practical, and effective in improving conceptual understanding and learning motivation of Grade XI students on the topic of the respiratory system. The use of Katar-Bio is expected to provide a concrete solution to the low learning outcomes and limited student engagement in biology learning, which is often abstract and complex in nature.

METHOD

Type and Population of the Study

This study employed a research and development (R&D) approach, as it was intended to produce an educational product (Sugiyono, 2015) using the 4-D (Four-D) development model proposed by (Thiagarajan et al., 1974) namely *Define, Design, Development, Disseminate*. Inline with Waruwu (2024) This type of research is designed to produce a specific product as its final outcome. The study was conducted at Budi Agung Marelan Private Senior High School over a period of two months during the even semester of the 2024/2025 academic year. The population consisted of 30 students from Second class-XI MIA1 at the same school.

Research Procedure

The procedure began with the Define stage, which consisted of: (1) front-end analysis, aimed at identifying potentials and problems to support the development of the intended product; (2) learner analysis, conducted through the distribution of a student needs analysis questionnaire containing various questions related to student issues; (3) concept review, carried out through interviews with biology teachers to determine which biology topics are challenging to teach and to select the appropriate content for the instructional media to be developed; and (4) task analysis, which served to thoroughly identify the tasks within the selected topic, enabling the formulation of essential learning tasks. The learning process must align with the core competencies and skills. The identification of relevant skills was based on the learning outcomes outlined in the Merdeka Curriculum, specifically within Phase F. (5) Formulating Instructional Objectives (Specifying Instructional Objectives), this stage involves determining the indicators of learning achievement based on the official guidelines provided by the Ministry of Education and Culture (Kemendikbud) for the biology subject. The learning outcomes and learning objective flow were used as references in designing the instructional media (Kemendikbudristek BSKAP, 2022).

Design Stage, The design stage included the following components: (1) Text preparation, which was carried out by analyzing the content context of the instructional material, adapted from the Grade XI biology textbook based on the Merdeka Curriculum; (2) Media selection, which was adjusted to meet students' needs and to address existing learning problems; (3) Format selection, in which the

smart card media was designed using the Canva application with dimensions of 10 cm × 15 cm, printed on 200-gram art carton paper with a thickness of 2.3 mm. The cards used a combination of fonts, including *Tan Tankwood, Sans Serif,* and *Handyman*, with a color scheme of black, red, and white; and (4) Initial design, in which each card was equipped with illustrations and a QR code that links to instructional videos and quizzes.

Development Stage, The development stage consisted of the following activities: (1) Expert assessment, which included media and content validation by subject matter experts; (2) Developmental testing, carried out through limited product trials involving only Grade XI science students at Budi Agung Marelan Private Senior High School; (3) Validity testing, evaluated based on questionnaire responses from both teachers and students regarding the developed biology smart cards; and (4) Packaging, which involved the final preparation and refinement of the learning media for classroom implementation.

Instruments

The instruments used in this study included: (1) Interview and teacher observation sheets, aimed at gathering information about the existing classroom learning process; (2) Media expert validation sheet; (3) Content expert validation sheet; (4) Learning motivation questionnaire; (5) Student response questionnaire, used to assess the usability, visual appeal, and usefulness of the media in the learning process; and (6) Teacher response questionnaire, intended to evaluate the practicality of the product in terms of content relevance, visual presentation, and ease of implementation in the classroom.

Data Analysis Technique

To produce a biology smart card that is valid, practical, and effective, this study employed data analysis techniques using both quantitative (validity, practicality, and effectiveness) and qualitative data (feedback, evaluation, and recommendations). Validity analysis was based on the results of expert validation conducted by media and content specialists. The instruments were first reviewed and approved by instrument validators before validation. The validation results were then analyzed using a Likert scale, as presented in Table 1.

Table 1. Likert Scale Scoring Guidelines Refers to Sugiyono (2015)

Score	Assessment Criteria
4	Very good
3	Good
2	Fair
1	Poor

Validation Data Analysis

The validation process was carried out by two validators, consisting of one media expert and one content expert, both of whom had educational backgrounds and experience in the field of biology instructional media development.

1. Media Expert
   The assessment instrument from the media expert consisted of two aspects: the graphic aspect, which included 8 items, and the presentation aspect, which also comprised 8 items. In total, the media expert validation questionnaire consisted of 16 questions.
2. Content Expert
   The content expert conducted validation based on two aspects: the content aspect, which included 12 items, and the presentation aspect, which consisted of 2 items, resulting in a total of 14 items on the content expert validation questionnaire.

The calculation formula for the validation sheet uses Formula 1 refers to (Ikhwani & Kuntjoro, 2021). The obtained validation scores were subsequently calculated based on the percentage standard, as shown in Table 2. The percentage was calculated using the following formula 1.

$$\text{Percentage} = \frac{Score\ Obtained}{Maximum\ Score} \text{ x } 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Table 2. Validation Assessment Criteria Refers to Sugiyono (2015)

Percentage (%)	Assessment Criteria
76-100	Very valid
56-75	Valid
40-55	Less Valid
0-39	Not Valid

Practicality Data Analysis

The practicality and effectiveness of the smart card can be evaluated based on the responses obtained from 30 students using a questionnaire consisting of 11 items, and from a teacher using a questionnaire comprising 19 items. The assessment of the developed instructional media encompasses three evaluated aspects: content, learning motivation, and media presentation. The data analysis regarding the practicality of the biology smart card as a learning medium was calculated using the following formula refers to Maharani et al., (2023). The formula used for the analysis is as follows, and the criteria for determining the level of practicality can be seen in Table 3.

$$\text{Practicality (\%)} = \frac{Total\ Score\ Obtained}{Maximum\ Possible\ Score} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Table 3. Practicality Assessment Criteria Refers to Sugiyono (2015)

Percentage (%)	Assessment Criteria
81 - 100	Very Practical
61 - 80	Practical
41 - 60	Less Practical
21 – 40	Not Practical

Effectiveness Data Analysis

The effectiveness of the Biology smart card was assessed using research instruments consisting of ten multiple-choice questions designed to measure students' conceptual understanding of the subject matter, and a motivation questionnaire comprising twenty items. These instruments were administered to students during the implementation phase of the developed learning media. The data collected were then analyzed using a percentage-based formula to evaluate the level of conceptual understanding (Umam & Zulkarnaen, 2022). The interpretation of students' conceptual understanding scores is presented in Table 4. The percentage of correct answers is calculated using the following formula 3.

$$x = \frac{a}{b}\ x\ 100\ \% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Description:
x = percentage of correct student answers
a = Total score of correct answers
b = Maximum possible score

Table 4. Conceptual Understanding Criteria, Refers to Umam & Zulkarnaen (2022)

Percentage (%)	Level of Understanding
0 - 20	Very Poor
21 - 40	Poor
41 - 60	Fair
61 - 80	Good
81 - 100	Excellent

To determine the improvement in students' conceptual understanding, the N-Gain score was calculated by measuring the difference between the pretest scores (before treatment) and the posttest scores (after treatment). The N-Gain calculation was conducted based on the formula 4 and the classification of N-Gain scores proposed by Hake (1998) which presented in Table 5 as follows:

$$N\text{-}Gain = \frac{Postest\ Scor - Pretest\ Score}{Maximum\ Score - Pretest\ Score} \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

Table 5. N-Gain Score Classification

No.	N-Gain Value	Category
1	G > 0.7	High
2	0.3 ≤ G ≤ 0.7	Medium
3	G > 0.3	Low

Learning Motivation Data Analysis

Analysis of students' learning motivation can observed through an observation sheet. The instrument for observing student motivation was constructed based on indicators that refer to the ARCS Motivation Model theory developed by Keller (1987), which includes four main components: Attention, Relevance,

Confidence, and Satisfaction. In this study, the indicators used consisted of six aspects, namely: (1) the desire and willingness to succeed, (2) the drive and need to learn, (3) future hopes and aspirations, (4) recognition in learning, (5) engaging learning activities, and (6) a conducive learning environment. Each indicator was measured using several statement items using a Likert scale. The interpretation of the score was presented in Table 6 refers to Jannah et al., (2022), namely the Average Percentage of Students' Learning Motivation.

$$\text{Students' Learning Motivation (\%)} = \frac{Total\ Score\ Achieved\ by\ Students}{Maximum\ Score}\ X\ 100 \quad \ldots\ldots \quad (5)$$

Table 6. Student Motivation Response Criteria

Score	Asesment Criteria
4	*Strongly Agree*
3	*Agree*
2	*Disagree*
1	*Strongly Agree*

Table 7. Motivation Criteria Standard Refers to Muthmainnah et al., (2020)

Percentage (%)	Criteria
81 - 100	Very Good
61 - 80	Good
41 - 60	Fair
21 - 40	Poor

RESULT AND DISCUSSION

Based on the research, a biology smart card learning media (Katar-Bio) was successfully developed to enhance conceptual understanding and learning motivation among Second Grade-XI MIA1 students at Budi Agung Private Senior High School, Marelan. The Katar-Bio smart card media development process in this study was guided by the 4D development model, which consists of four phases: Define, Design, Develop, and Disseminate. However, due to time and budget constraints, the scope of this research was limited to the development phase only. A detailed description of each stage implemented in the development of the Katar-Bio media was presented as follows.

Define Phase (Definition)

The define phase is intended to identify learning needs and gather relevant data concerning the instructional media to be developed. This phase consists of five segments, namely:

Front-End Analysis

In this stage, interviews were conducted regarding the biology learning process at Budi Agung Private Senior High School, Marelan. Questionnaires and interview sheets were used in this study to assess the needs of both teachers and

students. The interview results revealed several issues encountered during the learning process, particularly regarding the use of instructional media. Challenges identified during classroom implementation indicated that biology teaching largely relied on lecture methods, limited use of PowerPoint presentations, and a strong dependence on textbooks and board illustrations.

The analysis at this stage highlighted an urgent need for interactive and engaging instructional media. The problems identified, such as the dominance of traditional lectures and the minimal use of visual media, are consistent with the findings of (Mufidah & Habibi, 2022), who stated that students tend to struggle in understanding abstract concepts such as the respiratory system when the material is delivered solely through verbal explanations. Therefore, an innovative card-based approach is considered a relevant solution to address these challenges.

Learner Analysis

The learner analysis conducted in this study was intended to identify the characteristics of the students, particularly concerning the commonly used learning materials, the influence of learning content on students, preferred instructional media, their enthusiasm for learning biology, and their prior knowledge of the biology smart cards (Katar-Bio). At this stage, interviews were conducted with several students from Grade XI of SMA Swasta Budi Agung Marelan. The results of the interviews revealed several issues, one of which was the ineffectiveness of teaching aids frequently used by teachers in helping students comprehend the subject matter. Additionally, when teachers relied heavily on conventional learning media such as textbooks, students found it difficult to process the material and experienced challenges in maintaining focus during lessons that were primarily delivered through lectures. As a result, students often required repeated explanations to understand the material being taught.

Task Analysis

The task analysis focused on reviewing the learning outcomes (CP), learning objectives (TP), indicators, and subject content that would be used to develop the biology smart card learning media (Katar-Bio). The instructional design was aligned with the competency standards outlined in the Merdeka Curriculum, particularly those related to skill development in Phase F. This analysis ensured that the developed media would support the achievement of expected student competencies and learning goals.

Concept Analysis

Concept analysis aimed to determine the core content to be included in the learning media being developed. This stage was carried out through interviews with biology teachers to identify topics in the subject that were difficult to teach or commonly presented instructional challenges. Based on this input, relevant and essential biology content was selected to be incorporated into the smart card media.

Specifying Instructional Objectives To formulate the instructional objectives, an analysis was conducted based on the official learning outcomes and trajectories issued by the Ministry of Education and Culture (Kemendikbud) within the Merdeka

Curriculum framework. These objectives were then integrated with the content presented in the biology smart cards. The instructional objectives included: (1) identifying the relationship between the structure of respiratory system tissues and the biological processes involved, to explain the respiratory process and associated disorders through literature studies, observation, experimentation, and simulation; and (2) compiling, implementing, and presenting findings from data analysis sourced from literature, observations, experiments, and simulations related to the effects of air pollution such as emissions from vehicles, cigarette smoke, haze, and abnormalities in the structure and function of respiratory tissues on human health.

Design Phase

In this phase, the learning media were designed to be both visually appealing and interactive, taking into account the characteristics and learning needs of the students. The integration of QR codes linking to educational videos and online quizzes served to enhance student engagement. Using attractive visual elements and applying contrasting fonts and colors aligns with the instructional media design principles proposed by Azhar & Arsyad (2017), emphasizing that effective media should be communicative, engaging, and user-friendly for learners. The instructional media design process in this study included the following components:

1. Text Preparation: The learning content was carefully reviewed and adapted to match the context of the subject matter, based on the Grade XI biology textbook aligned with the Merdeka Curriculum.
2. Media Selection: The choice of media was adjusted to meet student needs and address the specific learning challenges previously identified during the learner analysis phase.
3. Format Selection: The biology smart cards were designed using the Canva application with dimensions of 10 cm x 15 cm, printed on 200-gram art card paper with a thickness of 2.3 mm. The design combined multiple font styles, namely Tan Tankwood, Sans Serif, and Handyman, using a color palette of black and white to maintain visual clarity and appeal.
4. Initial Design: Each card was equipped with illustrations and embedded QR codes that linked directly to related instructional videos and quizzes, providing an interactive experience for students.

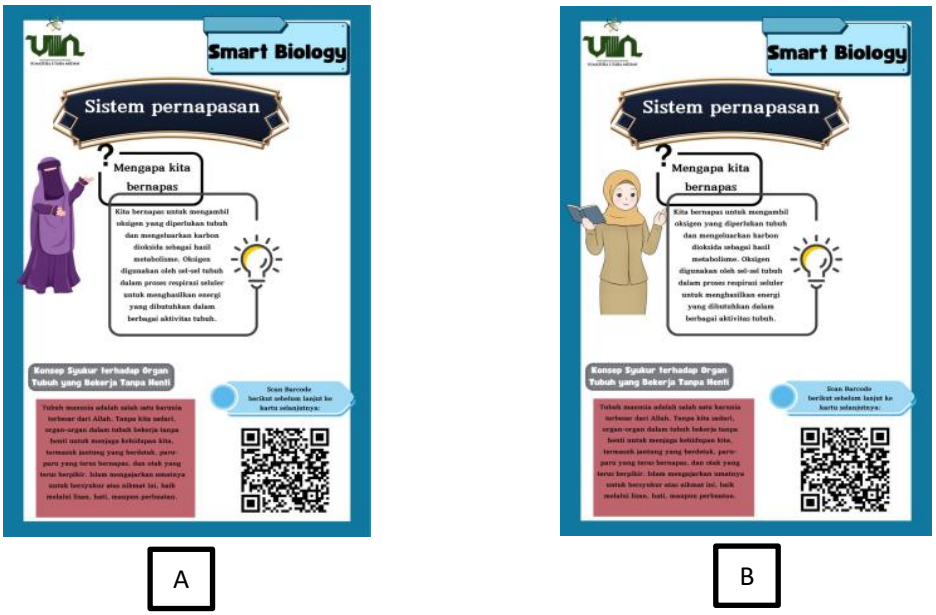
Development Phase

Results of Media Expert Validation

The media were validated by experts specializing in interactive instructional media, particularly those based on biology smart cards, to ensure the validity and quality of the developed product. Tables 8 and 9 present the media and content validation results, respectively.

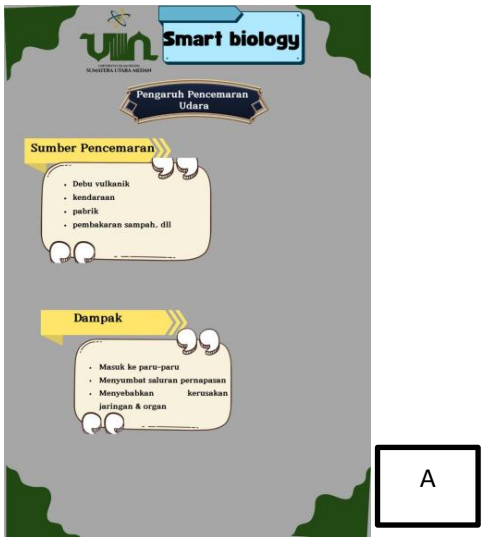
Figure 1. Front and back view of the media container before (A) and after (B) revisions based on media expert suggestions

Figure 2. Card content display before (A) and after (B) revisions based on expert suggestions



A B

Figure 3. Card content display before (A) and after (B) revisions based on expert recommendations



A

Figure 4. Recommendation of the media expert suggesting that each instructional material should be complemented with illustrative images to improve content clarity and learner comprehension

Table 8. Results of Media Expert Validation Test

Aspect	Score Obtained	Maximum Score	Precentage (%)	Criteria
Graphics	29	32	91	Highly Valid
Presentation	32	32	100	Highly Valid
Total	**61**	**64**	**95**	**Highly Valid**

The media expert provided revisions based on Figures 1(A) and 1(B), which depict the appearance of the smart card container. For the front side of the container, the illustration was recommended to be modified to avoid potential misconceptions—for instance, replacing the image of lungs being held by a human hand. This visual was considered inappropriate and potentially misleading in terms of conceptual understanding. As for the back side of the container, the expert suggested the removal of the previously included material. This revision encouraged students to explore the media content independently, promoting active learning. In Figures 2(A) and 2(B), the expert advised that the card's front cover should not display content material directly. Instead, it should contain only the identity of the media and an appealing supporting visual. This suggestion was made considering the diverse religious backgrounds present in schools, emphasizing the importance of inclusive visual design. Further, in Figures 3(A) and 3(B), the media expert recommended replacing the illustration of a veiled individual, as it may not represent all students' cultural and religious diversity. Lastly, Figure 4 reflects the expert's recommendation that relevant and concrete illustrations should accompany each card. This approach is intended to enhance conceptual understanding by providing clearer visual representations of the content.

Based on the results of media expert validation, which encompassed two aspects graphics and presentation the scores obtained were 29 and 32 out of a maximum of 32 for each aspect, respectively. The total score was 61 out of 64, equivalent to 95%, and was categorized as "highly valid." This high percentage not only reflects the technical visual appropriateness of the media but also indicates its success in fulfilling pedagogical principles such as readability, aesthetics, design consistency, and inclusivity. The validity of the media was supported by a development process that was responsive to expert feedback. Revisions included improving illustrations that initially had the potential to cause misconceptions, eliminating biased elements, and adding concrete visual representations to enhance conceptual visualization. This is in line with the opinion of (Azhar & Arsyad, 2017), who emphasized that visual media should be able to convey instructional messages clearly while also being aesthetically appealing Research by (Laula et al., 2023) has shown that learning media based on QR code technology can strengthen interactivity and improve student focus on the presented material, Similarly (Cacik et al., 2022) asserted that media validity can be significantly enhanced through design processes grounded in expert input and aligned with students' learning needs. Furthermore, these findings are consistent with those of Nasihah et al., (2024) who found that learning media with inclusive and interactive visual designs promote active student participation and foster deeper conceptual understanding, especially in complex subjects such as biology.

Results of the Content Expert Validation Test

Figure 5. Suggestions from the subject matter expert include adding numbering to each image and reviewing typographical errors found in the content of the media.

The subject matter expert evaluated the respiratory system material presented in the interactive smart card-based learning media to assess the appropriateness of the high school biology content for Grade XI. Based on the data analysis, the evaluation results are presented in Table 9.

Table 9. Results of Content Validation Data Analysis

Aspect	Score Obtained	Max. Score	Precentage (%)	Criteria
Learning Content	40	48	83.0%	Highly Valid
Content Presentation	4	8	50%	Less Valid
Total	**44**	**56**	**79%**	**Highly Valid**

Based on the data analysis presented in Table 9, it was found that the content validation by the subject matter expert focused on two aspects: content and presentation. The content aspect received a score of 40 out of 48 (83%), categorized as highly valid, while the presentation aspect scored 4 out of 8 (50%), which falls under the less valid category. The total score obtained was 44 out of 56, equivalent to 79%, indicating that the media is generally highly valid and suitable for use in learning activities. In response to these results, the researcher implemented several revisions to improve the material's presentation, as the validator recommended. These improvements included adding image numbering, correcting typographical errors, and restructuring the content to enhance coherence and readability. With these revisions, the final version of the media has been refined and optimized for instructional use.

These findings are supported by Cacik et al., (2022) who stated that a well-organized, systematic, and visually appealing presentation of learning media

significantly enhances content validity. Furthermore, according to Azhar & Arsyad (2017), the quality of visual design and the coherence of content play a crucial role in determining the effectiveness of the instructional message conveyed through educational media. Similarly, Ghozali & Zulfah (2023), emphasized that constructive responses to validator feedback can substantially improve the quality and feasibility of the developed learning materials. Therefore, the revisions carried out in this study have rendered the Katar-Bio media suitable for application in biology instruction, particularly on the topic of the respiratory system.

Table 10. Analysis Results of Student Response Data

Score Obtained	Maximum Score	precentage	Criteria
1,213	1,320	92%	Very Practical

Table 11. Analysis Results of Teacher Response Data

Aspect	Total Score	Score Maximum	Precentage (%)	Criteria
Learning Content	30	32	94	Very Practical
Learning Motivation	12	12	100	Very Practical
Learning Media Presentation	31	32	97	Very Practical
Total	**73**	**76**	**96**	**Very Practical**

Based on Table 10, the results of the practicality test—measured through a student response questionnaire involving 30 participants—showed a total score of 1,213 out of a possible 1,320 points, equivalent to 92 %. This percentage indicates that the developed interactive biology learning media, based on smart cards, is classified as highly practical for student use. The high level of practicality suggests that students found the media easy to use, engaging, and helpful in mastering the topic of the respiratory system. These results reflect the media's effectiveness in facilitating student interaction with the material while also supporting their conceptual understanding in a user-friendly and attractive format.

Based on Table 11, the practicality test evaluated from the teacher's perspective was assessed across three aspects: learning material content, learning motivation, and media presentation. The content aspect received a scored of 30, the motivation aspect scored 12, and the media presentation aspect obtained 31, resulting in a total score of 73 out of a maximum of 76. This corresponds to a percentage of 96%, categorizing the media as highly practical. In detail, the learning content aspect achieved a scored of 94%, the motivation aspect reached 100%, and the media presentation aspect attained 97%. These findings affirm that, from the educator's viewpoint, the smart card-based interactive learning media is considered highly feasible and effective for classroom implementation. The consistently high percentages across all evaluated aspects further demonstrate the media's potential to support both instructional delivery and student engagement in the learning process.

The high practicality scores from both students (92%) and teachers (96%) indicate that the media is highly responsive to user needs. Its simplicity, ease of use, and content relevance were perceived as significantly supportive in facilitating the

learning process. These findings are consistent with the study conducted by Nasihah et al., (2024), who developed a learning media through Google Sites using a STEM-PjBL approach for teaching invertebrate material. Their research reported practicality percentages of 94.33% from students and 86.83% from biology teachers, both of which were categorized as highly practical. Similarly, Kustyarini et al., (2020) emphasized that media practicality was determined by ease of access, flexibility in use, and content relevance. Furthermore, the study by Rahma et al., (2024) revealed that interactive and easily accessible media can enhance students' focus and enthusiasm during learning. Collectively, these studies support the present findings, reinforcing the value of user-oriented design in the development of practical and effective instructional media.

Table 12. Effectiveness Test Results Based on N-Gain

Average Pretest	Average Posttest	Posttest - Pretest	Max Score	Max Score - Pretest	N-Gain Score	N-Gain (%)	Criteria
43	87.2	44.2	100	57	0.8019	80.19	Effective

Based on Table 12, the average pretest score of students was 43, while the posttest score reached 87.2, indicating an improvement of 44.2 points. Using the N-Gain formula, the calculated N-Gain score was 80.19 %, which falls within the high category and was classified as effective in enhancing conceptual understanding. These results support the findings of Rachmawati (2024), who stated that learning media integrating simple technologies, such as QR codes, have been proven to improve student engagement and learning outcomes. The substantial gain observed in this study further confirms the media's effectiveness in promoting meaningful learning, particularly on complex topics such as the respiratory system.

The N-Gain score indicates that the Katar-Bio interactive learning media—or Biology Smart Card—is efficacious in improving students' understanding of the respiratory system material in Grade XI. This effectiveness is evidenced by the significant increase in students' scores from the pretest to the posttest, demonstrating the media's capability to enhance conceptual mastery through an engaging and structured learning experience.

These findings are consistent with a study conducted by Miskiyah & Safitri (2023) published in Al-Kawnu Journal, which demonstrated that the use of smart card media had a significant impact on students' learning enthusiasm and academic performance in the topic of ecosystems. The Independent Sample t-test analysis results revealed a significance value of 0.004, indicating a statistically significant difference between the experimental and control groups. This suggests that the smart card media contributed meaningfully to the observed learning gains.

In addition, a study by Emawati (2021) rom Raden Intan State Islamic University of Lampung demonstrated that the development of biology smart card media integrated with Augmented Reality technology effectively fosters students' Habits of Mind. During the expert validation process, each aspect—content, language, and media—received high percentage scores of 95%, 98%, and 94%,

respectively. These results fall under the highly appropriate category, indicating that the media was considered highly feasible for instructional use based on expert evaluations.

Thus, based on the results of the effectiveness test and supported by findings from previous studies, the interactive learning media developed in this study—based on smart card technology—can be considered highly effective and suitable for use in teaching and learning activities.

Table 13. Students' Motivation Score Results

No	Motivation Indicator	Total Score (Pretest)	Precentage (%)	Total Score (Posttest)	Presentage (%)
1.	Desire and ambition to succeed	280	58.33	439	91.45
2.	Drive and need for learning	205	56.94	312	86.66
3.	Hopes and future aspirations	225	62.50	347	96.38
4.	Recognition and appreciation in learning	191	53.05	271	75.27
5.	Involvement in interesting activities	234	48.75	417	86.87
6.	Conducive learning environment	191	53.05	295	81.94
	Total	**1,326**	**55.25**	**2,801**	**86.70**

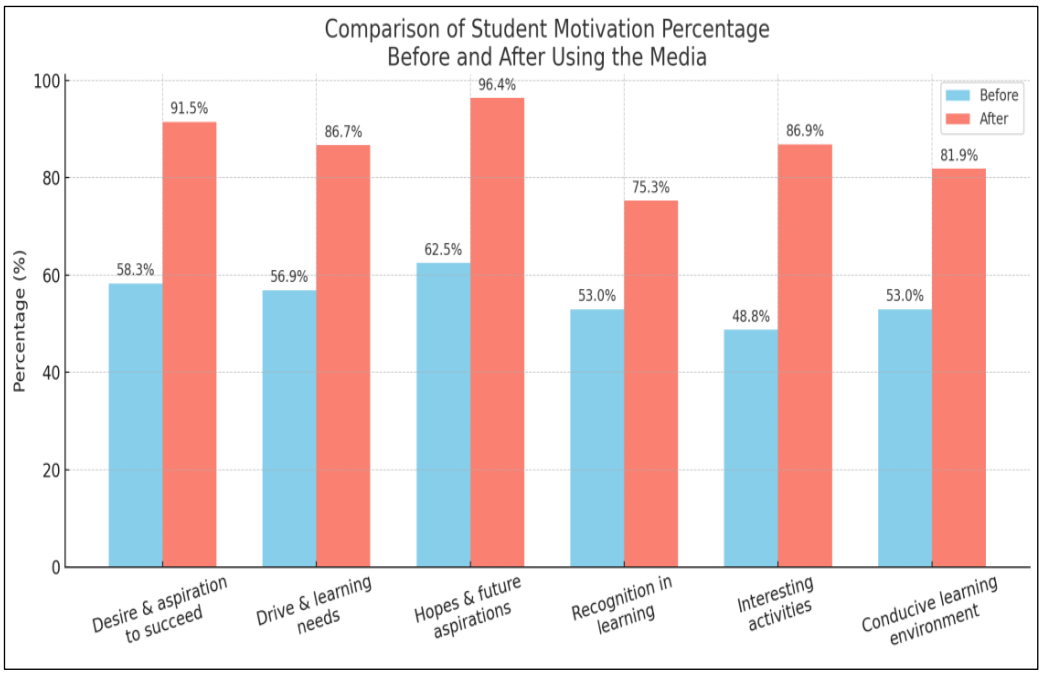


Figure 6. Students' Motivation Before and After Treatmen

Based on Table 13 and Figure 6, it can be observed that there was a significant increase in learning motivation among Grade XI students following the implementation of the instructional intervention using the developed media. The measurement of learning motivation was conducted using six indicators: (1) the desire and willingness to succeed, (2) the drive and need to learn, (3) future goals and aspirations, (4) appreciation of learning efforts, (5) engaging and attention-grabbing activities, and (6) a conducive learning environment. The increase in students' motivation after the use of Katar-Bio media—by 31.45 % (from 55.25 to 86.70 %) - not only demonstrates numerical effectiveness but also reflects the strong relationship between the design of interactive media and the psychological mechanisms underlying student motivation. This finding highlights the potential of well-designed instructional media to influence affective learning outcomes alongside cognitive achievement positively.

The Katar-Bio media was designed by integrating QR codes that link to instructional videos and online quizzes and incorporating concise and visually appealing content. These components directly contribute to the elements of Attention, Relevance, Confidence, and Satisfaction (ARCS) in Keller (1987) about the motivational design model. Results from observations and questionnaires indicated that the most significant increase in motivation occurred in the attention-grabbing activities indicator, which rose by 38.12 %, followed by future aspirations (an increase of 33.88 %) and the desire to succeed (an increase of 33.12 %). These improvements demonstrate the media's effectiveness in stimulating key motivational factors essential for sustained engagement and academic success.

The observed increase in these indicators aligns with the findings of Zhou & Zhang (2025), who reported that using technology-based media, such as QR codes, significantly enhances students' focus and motivation to complete learning tasks through visual appeal and high interactivity. In this context, the learning process becomes more personalized, autonomous, and enjoyable, positively impacting cognitive and affective student engagement. Furthermore, Kandiri et al., (2025), emphasized that QR-based media allows students to access content flexibly, thereby increasing their confidence as they are able to learn at their own pace. This aligns with the observed improvements in the drive to learn and conducive learning environment indicators, both of which increased by more than 28 %. The media design also fulfills the satisfaction element of the ARCS model, as it fosters a pleasant and rewarding learning experience. Herianto & Wilujeng (2021) also noted that multimedia incorporating immediate feedback and engaging visual elements can significantly enhance student satisfaction, particularly in abstract science subjects such as the respiratory system. Overall, the pattern of motivational gains reflected across all six indicators in the motivation diagram confirms that the Katar-Bio media is not merely a tool for delivering information but also a mechanism that activates key psychological factors essential for effective modern learning. Thus, the correlation between increased motivation and media design in this study is grounded in both theoretical and empirical evidence.

Based on the analysis results, the interactive learning media based on smart biology cards (Katar-Bio) developed in this study has proven effective in enhancing the quality of biology learning, particularly on the topic of the respiratory system.

This media is designed to facilitate conceptual understanding through engaging visual approaches and the integration of digital technology, thereby fostering students' learning interest and active participation.

The use of Katar-Bio media encourages students to actively engage in the learning process, both individually and collaboratively. Through interactive features such as QR codes linking to instructional videos and online quizzes, the media enriches the learning experience and expands students' access to diverse and contextual materials. Students are guided to deeply comprehend concepts through visual illustrations, reflective activities, and challenging practice questions. The media's concise, communicative, and user-friendly design makes the learning process more efficient and meaningful. Moreover, the media encourages students to think critically, act creatively, and collaborate in solving problems or answering questions related to the subject matter. Student participation during lessons also increases, as they feel more interested and comfortable using media that aligns with the characteristics of today's digital-native generation.

Students demonstrated increased learning motivation and improved conceptual understanding through more interactive and enjoyable learning activities. This indicates that the Katar-Bio media can serve as an innovative alternative learning tool, aligned with the principles of differentiated instruction and the Merdeka Curriculum. The media is deemed appropriate for implementation in biology instruction as a means to foster an active, adaptive, and student-centered learning environment.

CONCLUSION

Based on the results of research and development of the interactive biology smart card learning media (Katar-Bio) for the respiratory system topic in Second Grade-XI, it can be concluded that the developed media is valid, practical, and effective. Validation by media experts yield a score of 95 %, and validation by subject matter experts reached 79 %, both of which fall into the category of highly valid. In terms of practicality, the media received positive responses from both teachers and students, with scores of 96 % and 92 % respectively, which are categorized as highly practical. The Katar-Bio media is easy to use, engaging, and contributes to enhancing students' active participation. Effectiveness testing indicated an improvement in conceptual understanding, with an N-Gain score of 0.80 (high/effective category), and increase in students' learning motivation with 31.45 %, based on six motivation indicators analyzed both quantitatively and qualitatively. This research affirms that the integration of simple media such as smart cards equipped with QR codes can significantly impact students' understanding and motivation, particularly in abstract topics like the respiratory system. The practical implication is that teachers can utilize similar media to promote active, independent, and enjoyable learning without relying on complex digital technologies. Although the research yielded positive outcomes, several limitations were identified. This study involved only a small class in a single school and did not include a control group. Thus, Katar-Bio has the potential to become an innovative alternative learning medium that not only supports students'

cognitive achievement but also fosters motivation and meaningful learning experiences.

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REFERENCES

Afnita, N., Sari, D. P., Arafat, A., Putra, F. W., & Wandi, J. I. (2023). Improving Student Motivation Through Audio-Visual Learning Media. *Jurnal Pendidikan (Teori Dan Praktik)*, *7*(2), 126–130. https://doi.org/10.26740/jp.v7n2.p126-130 **[*In Indonesian language*]**

Azhar, & Arsyad. (2017). *Learning Media. Revise Edition*. Jakarta : Rajawali Press. **[*In Indonesian language*]**

Bahtiar, A. Z., & Surjono, H. D. (2020). Teacher and Student Perspective of Using the Quick Response Code Feature in the Biology Module. *Proceedings of the International Conference on Online and Blended Learning 2019 (ICOBL 2019), 440*, 201–206. https://doi.org/10.2991/assehr.k.200521.045

Damayanti, A., & Jayanti, U. N. A. D. (2024). Development of biology smart card learning media based on character education in immune system material. *BIO-Inoved : Jurnal Biologi-Inovasi Pendidikan*, *6*(2), 179. https://doi.org/10.20527/bino.v6i2.19155

Emawati, D. (2021). Development of Medisa Smart Biology Cards with Augmented Reality Technology to Improve Higher-Order Thinking Skills in Grade X. Undergraduated Theses of *Faculty of Tarbiyah and Teacher Training UIN Raden Intan Lampung*, http://repository.radenintan.ac.id/. Accessed on 3Rd March 2025) **[*In Indonesian language*]**

Ghozali, M. D. H. A., & Zulfah, A. (2023). Development of Interactive Learning Media for Pegon Vocabulary Based on Technology in Ro'Sun Sirah and Tahajji Materials for Primary School Students. *Jurnal Review Pendidikan dan Pengajaran (JRPP), 6(4)*, 3980–3989. http://journal.universitaspahlawan.ac.id/index.php/jrpp/article/download/23273/16326 **[*In Indonesian language*]**

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Herianto, & Wilujeng, I. (2021). Increasing the attention, relevance, confidence and satisfaction (Arcs) of students through interactive science learning multimedia. *Research in Learning Technology*, *29*(1063519), 1–13. https://doi.org/10.25304/rlt.v29.2383

Ikhwani, P. N., & Kuntjoro, S. (2021). Development of Guided Inquiry-Based Electronic Student Activity Sheets (E-LKPD) on Environmental Change Material to Train Critical Thinking Skills in Grade X High School Students. *Berkala Ilmiah Pendidikan Biologi (BioEdu)*, *10*(3), 597–604. https://doi.org/10.26740/bioedu.v10n3.p597-604 **[*In Indonesian language*]**

Inu, A. N. N. A., Fitriani, D., Bani, E. A. S., & Winandar, M. L. (2023). The Role of Teachers as Agents of Change in Improving the Quality of Innovative Learning in Primary Schools. *Journal on Education*, *5*(2), 1696–1701. https://doi.org/10.31004/joe.v5i2.806 **[*In Indonesian language*]**

Jannah, N. N., Afrilianto, M., Siliwangi, I., Terusan, J., Sudirman, J., Cimahi, J., & Barat, I. (2022). Improving Student Motivation and Learning Outcomes in Sequences and Series Using the Reward Method. *Jurnal Pembelajaran Matematika Inovatif*, *5*(5), 1291–1302. https://doi.org/10.22460/jpmi.v5i5.1291-1302 **[*In Indonesian language*]**

Kandiri, K., Nurwahidin, M., Aransyah, A., & Purmadi, A. (2025). Development of Qr-Code Media-Based Modules in Constructing Learning to Increase Learning Motivation. *Jurnal Teknologi Pendidikan : Jurnal Penelitian Dan Pengembangan Pembelajaran*, *10*(1), 191. https://doi.org/10.33394/jtp.v10i1.14577

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development, 10*(1932), 2–10.

Kemendikbudristek BSKAP. (2022). Decision of the Head of the Education Standards, Curriculum, and Assessment Agency, Ministry of Education, Culture, Research, and Technology Number 008/H/KR/2022 concerning Learning Outcomes in Early Childhood Education at the Primary Education Level and Secondary Education Level.. In *Kemendikbudristek* (Issue 021). Laman litbang.kemdikbud.go.id **[*In Indonesian language*]**

Kustyarini, K., Utami, S., & Koesmijati, E. (2020). The Importance of Interactive Learning Media in a New Civilization Era. *European Journal of Open Education and E-Learning Studies*, *5*(2), 48–60. https://doi.org/10.46827/ejoe.v5i2.3298

Laula, V., Hutahaean, S. D., & Nawir, M. (2023). Development of QR Code Card-Based Learning Media for Simple Aircraft Material in Grade VIII at SMP Negeri 14 Palangka Raya. *Bahana Pendidikan: Jurnal Pendidikan Sains*, *5*(1), 30–36. https://doi.org/10.37304/bpjps.v5i1.8860 **[*In Indonesian language*]**

Maharani, U. Z., Rohana, R., & Hera, T. (2023). Development of Interactive E-Modules for Mathematics on Data Compilation for Grade IV Elementary

School. *JRPD (Jurnal Riset Pendidikan Dasar)*, *6*(2), 123–133. https://doi.org/10.26618/jrpd.v6i2.11749 **[*In Indonesian language*]**

Miskiyah, Z., & Safitri, N. L. (2023). The Effect of Smart Card Media Use on Motivation and Learning Outcomes of High School Students Studying Ecosystems. *Al Kawnu : Science and Local Wisdom Journal*, *2*(2), 155–162. https://doi.org/10.18592/ak.v2i2.7444 **[*In Indonesian language*]**

Mufidah, L., & Habibi, M. W. (2022). The Validity of Web-Based Learning Media on Human Respiratory System Material for Grade VIII Junior High School Students. *Bioeduca : Journal of Biology Education*, *4*(1), 57–66. https://doi.org/10.21580/bioeduca.v4i1.10851 **[*In Indonesian language*]**

Muthmainnah, S., Fatmawati, L., Krismilah, T., & Hartini, S. (2020). Motivation and Learning Outcomes Improvement through Utilisation of the Surrounding Environment as a Learning Resource for Grade 3B Students at SDN Tegalrejo 3 Yogyakarta. *Prosiding Pendidikan Profesi Guru Fakultas Keguruan Dan Ilmu Pendidikan, Universitas Ahmad Dahlan*, 232–242. **[*In Indonesian language*]**

Nainggolan, Y., Tanjung, N. H. M., Monika, S. A., & Bakti, M. A. (2024). Learning Models in Education. *Pendidikan Inklusif*, *8*(7), 27–31. **[*In Indonesian language*]**

Nasihah, S. A., & Utami, R. P. (2024). Validity And Practicality Of The Results Of The Development Of Google Sites Learning Media Base On Tem-Pjbl On Invertebrate Material In Class X Sma With Independent Curriculum. *Jurnal Inkredibel, 1*(2), 116–123. **[*In Indonesian language*]**

Rachmawati. (2024). The Effectiveness of Using QR Code-Based Presentation Slides in Mathematics Learning at Muhammadiyah 1 UNISMUH Makassar High School. *Jurnal Αγαη*, *15*(1), 37–48. **[*In Indonesian language*]**

Rahma, J., Nawir, M., & Nasir. (2024). The Effect of Interactive Multimedia on the Motivation to Learn Science Among Seventh Grade Students at SMP Negeri 11 Satap Pulau Masalima Liukang Kalmas, Pangkep Regency. *Didaktik : Jurnal Ilmiah PGSD STKIP Subang*, *10*(3), 302 - 312. https://doi.org/10.36989/didaktik.v10i3.3839 **[*In Indonesian language*]**

Smith, M., Segura-Totten, M., & West, K. (2018). QR Code Lecture Activity as a Tool for Increasing Nonmajors Biology Students' Enjoyment of Interaction with Their Local Environment. *Journal of Microbiology & Biology Education*, *19*(1), 1-6. https://doi.org/10.1128/jmbe.v19i1.1453

Sugiyono. (2015). *Quantitative and qualitative research methods and R&D*. Bandung: CV.Alfabeta. **[*In Indonesian language*]**

Sutikno, Y., Hosan, H., & Irawati, I. (2022). The Role of Teachers in Improving Learning Quality. *Jurnal Maitreyawira*, *3*(2), 1–6. https://doi.org/10.69607/jm.v3i2.55 **[*In Indonesian language*]**

Cacik, S., Wulandari, T. S. H., Panggabean, C. I. T., & Widiyanti, I. S. R. (2022). The Feasibility of Tpack-Based E-modules for Training the Science Literacy Skills of Prospective Biology Teachers. *Jurnal Inovasi Pendidikan Dan Sains, 3*(3),

131-136. https://doi.org/10.51673/jips.v3i3.1253 **[*In Indonesian language*]**

Thiagarajan, S., Semmel, D. S., Semmel, M. I. (1974). *Instructional Develoment for Traning Teacher of Exeptional Children: A Sourcebook*. Reston, VA: Council for Exceptional Children. P 194.

Tomi, T., & Jamilah, J. (2020). Development of Biology Smart Card-Based Learning Media for Cell Material. *Al-Ahya: Jurnal Pendidikan Biologi*, *2*(1), 20201–20210. https://doi.org/103.55.216.56/index.php/alahya/article/view/11352 **[*In Indonesian language*]**

Umam, M. A., & Zulkarnaen, R. (2022). Analysis of Students' Mathematical Conceptual Understanding in Two-Variable Linear Equation Systems. *Jurnal Educatio FKIP UNMA*, *8*(1), 303–312. https://doi.org/10.31949/educatio.v8i1.1993 **[*In Indonesian language*]**

Waruwu, M. (2024). Research and Development (R&D) Methods: Concepts, Types, Stages, and Advantages. *Jurnal Ilmiah Profesi Pendidikan*, *9*(2), 1220–1230. https://doi.org/10.29303/jipp.v9i2.2141 **[*In Indonesian language*]**

Zhou, Q., & Zhang, H. (2025). Flipped Classroom Teaching and ARCS Motivation Model: Impact on College Students' Deep Learning. *Education Sciences*, *15*(4), 997 s/d 1012. https://doi.org/10.3390/educsci15040517

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