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Development of Interactive Digital Learning Based Liveworksheets to Improve Critical Thinking on Respiratory System For High School Student

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Abstract

Background: *The rapid advancement of information and communication technology demands innovative instructional strategies that foster 21st-century skills, particularly critical thinking. However, biology learning in schools remains predominantly conventional and lacks the integration of scientific-based digital media. The scientific approach and the Liveworksheets platform have become relevant tools as they support active, structured, and inquiry-based learning. This study aims to develop interactive digital student worksheets using the scientific approach by the Liveworksheets platform on the human respiratory system topic for the second grade students at Sinar Husni Helvetia Private High School.* **Methodology:** *Employing the Research and Development (R&D) method, this study adopted the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation.* **Findings:** *The validation results show the worksheets is highly valid, with scores of 88.33 % (media), 87.5 % (content), and 87.5 % (assessment). Practicality tests showed an average of 92 % indicating the liveworksheets is highly practical, with student responses (85 %) and teacher responses (93 %). Effectiveness tests demonstrated a significant improvement in students' critical thinking skills, with the average pre-test score of 47 increasing to 86.23 in the post-test, and an N-Gain score of 0.76, categorized as high. Data analysis was conducted quantitatively using percentage and N-Gain calculations. The novelty of this research lies in the direct integration of the scientific approach into the Liveworksheets platform in the form of a digital worksheets that systematically guides students through scientific stages.* **Contribution:** *The results of this development enrich the alternatives for valid, practical, and effective digital learning media that support critical thinking skills and reinforce technology-integrated biology learning at the high school level*

Keywords: *Critical Thinking; Interactive Worksheet; Liveworksheets; Scientific Approach*

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INTRODUCTION

The rapid advancement of science and technology (S&T) in the era of globalization has led to significant transformations in various sectors, including education (Hurrahma & Sylvia, 2022). Education today faces 21st-century challenges that require students to possess complex and adaptive skills. One of the key skills students must acquire is critical thinking, which is a part of the 4C competencies: critical thinking, creativity, collaboration, and communication (Nasrulloh et al., 2023). Among these, critical thinking holds a vital role as it aids students in analyzing information, evaluating data, and drawing conclusions as well as solving problems in a rational and objective manner (Alfiana et al., 2022).

Preliminary observations, conducted through interviews and needs assessments with biology teachers at SMA Swasta Sinar Husni, reveal that students' critical thinking abilities remain relatively low. This is largely due to a tendency to memorize material solely to achieve high grades rather than to deeply understand the content. The limited use of teaching media restricted mainly to school-issued textbooks is one of the main contributing factors. In addition, conventional learning strategies, such as discussions and practice questions, dominate classroom activities, often neglecting analytical and reflective learning processes. As a result, students tend to be passive and lack motivation to actively engage in meaningful learning experiences.

To address these issues, the scientific approach emerges as a suitable alternative for biology instruction. This approach emphasizes scientific processes involving five main stages: observing, questioning, experimenting, reasoning, and communicating (Sibuea & Sukma, 2021). It encourages students to actively participate in discovering and understanding concepts rather than passively receiving information. Moreover, the scientific approach supports contextual learning that fosters critical thinking through exploratory activities and real-world problem-solving (Pahrudin & Pratiwi, 2019; Rizky et al., 2025). To ensure its effective implementation, a teaching medium is required that can integrate scientific activities into an engaging and interactive digital format.

One such medium is interactive digital worksheets based on Liveworksheets. This platform enables teachers to convert traditional worksheets into digital formats accessible online, equipped with automatic feedback features and interactive elements (Riana et al., 2024; Sari & Putra, 2022). Previous studies have demonstrated the effectiveness of digital student worksheets in enhancing student learning outcomes and engagement. For example, Nugraheni (2022) and Sholehah (2021) reported that their developed of digital student worksheets received excellent responses and were validated by experts. Similarly, Sarah et al., (2022) found that 83% of students positively responded to their Liveworksheets-based student worksheets. However, to date, no research has specifically developed an interactive digital student worksheets integrating the scientific approach focused on the human respiratory system. This gap necessitates further study to support meaningful, contextual biology instruction.

Based on this background, the present study aims to develop an interactive digital student worksheets grounded in the scientific approach for the human

respiratory system topic, with the goal of enhancing students' critical thinking skills. The main contribution of this research lies in providing an innovative learning medium that not only integrates the scientific approach into a digital and interactive format but also specifically targets a topic human respiration that has yet to be widely explored in existing digital student worksheets. The novelty of this research is the integration of the scientific approach with the Liveworksheets platform within the context of the human respiratory system, a combination not previously investigated. This study is expected to serve as a valuable reference for developing contextual, effective, and 21st-century-relevant learning media.

METHOD

Type and Population of the Study

This study employed a Research and Development (R&D) approach to guide the process of product development and validation, aimed at improving and refining previously developed instructional tools or creating new and enhanced products. Referring to Sugiyono (2019), this research focused on the development of a new product in the form of interactive digital student worksheets based on the scientific approach using the Liveworksheets format. The development of the student worksheets followed the five stages of the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation.

This study was conducted at the Senior high school of SMA Swasta Sinar Husni Helvetia during the even semester of the 2024/2025 academic year. The school implements the 2013 Curriculum (K13), which emphasizes the development of 21st-century competencies, including critical thinking skills. The study involved the entire population of second grade students in Class XI IPA 2, totaling 26 participants. The sampling technique used was total sampling (saturated sampling), in which all members of the population were selected as research subjects. The second grade-Class XI IPA 2 was chosen due to its relatively small size, allowing it to represent the population directly. Furthermore, this class had already studied the human respiratory system, making it suitable for the implementation and trial of the developed interactive digital student worksheets.

Research Procedure

The research procedure followed five stages:

Analysis Stage

This stage focused on identifying the current conditions and context. Initial observations were carried out on learning activities in second grade-class XI at SMA Swasta Sinar Husni High School. The analysis included:

Teacher Needs Analysis

The analysis of biology teacher needs is a process aimed at identifying the resources and support required by teachers to ensure effective biology instruction. This includes the need for instructional materials, the types of teaching media utilized, and the challenges encountered during the teaching process. Data collection

was carried out through a teacher needs analysis questionnaire and semi-structured interviews (Firmansyah & Ardi, 2022).

The interviews with biology teachers covered several key indicators relevant to the development of the digital student worksheets. These indicators included teachers' experiences in delivering the respiratory system topic, challenges encountered in the classroom, teaching methods employed, and types of instructional media previously used. Additionally, the interviews explored obstacles in the learning process, the effectiveness of existing student worksheets, and teachers' perspectives on the application of the scientific approach in biology instruction. The discussions also examined the perceived importance of fostering critical thinking skills, the extent to which teachers encourage such skills through open-ended questioning, their familiarity with digital platforms such as Liveworksheets, and their interest in developing interactive digital student worksheets that integrate the scientific approach. Teachers were also asked to provide input regarding essential components that should be included in the student worksheets to better support biology learning, particularly in the context of the respiratory system topic.

Student Needs Analysis

The student needs analysis focused on identifying the specific requirements necessary to support student learning. This analysis was conducted by distributing a student needs questionnaire to determine what students require to effectively understand biology content, including the need for clear conceptual understanding and engaging, participatory instructional materials.

Design Stage

The design stage refers to the activity of planning the product to meet the intended objectives and needs (Jakaria & Sukmono, 2021). At this stage, the researchers outlined the planned structure of the student worksheets. The purpose of this stage was to facilitate the organization of ideas and the formulation of a systematic design for the development of the digital student worksheets.

Development Stage

At this stage, media validation was conducted (Lim et al., 2022). This included assessing the feasibility of the developed product by involving various experts, including content specialists, media experts, teachers, and students, to ensure the appropriateness and quality of the digital student worksheets. Specifically, two experts were engaged to evaluate the feasibility of the scientific approach-based interactive digital student worksheets: one expert in biology content and assessment, and one expert in instructional media. The selection of these experts was based on specific criteria, including having at least five years of professional experience in education or media development, as well as prior involvement in instructional material validation or development.

The validation process was carried out by providing each expert with an evaluation form containing assessment indicators across multiple aspects. Each indicator was rated using a Likert scale, accompanied by a comment section for

suggestions and revisions. The scores provided by each validator were then converted into feasibility percentages, which served as the basis for determining the validity level of the student worksheets. Expert feedback was also utilized to revise and refine the product prior to its implementation in the trial phase.

Implementation Stage

The implementation stage involved the actual use of the developed product. Once the media was approved as feasible by the validators, both pre-test and post-test were administered. The purpose of this phase was to determine whether the instructional intervention provided by the researchers could contribute to improving students' critical thinking skills (Komara et al., 2023).

Evaluation Stage

Evaluation is the process of examining the alignment between each procedural step and the outcomes produced, in accordance with the predetermined objectives and criteria (Cooksey & Jonsson, 2022).

Research Instrument

This study involved second grade students from Class of XI IPA 2 at SMA Swasta Sinar Husni Helvetia High School. The research instruments included interview guides and questionnaires used to analyze the needs of both students and teachers. In addition, student worksheets evaluation forms were employed, consisting of content and media validation sheets to assess the validity of the developed student worksheets. Other instruments included response questionnaires distributed to biology teachers and students to measure the practicality of the student worksheets. Furthermore, pre-tests and post-tests were administered to evaluate the effectiveness of the student worksheets.

Data Analysis

The collected data were analyzed using a combination of quantitative and qualitative methods. The qualitative approach involved gathering and analyzing suggestions and feedback from media validators, content validators, teachers, and students who studied the respiratory system topic. The results were then synthesized and presented descriptively. This qualitative analysis referred to the procedures described by deMarrais et al., (2024), which emphasize deep analysis of meaning, context, and social interaction when interpreting data collected from validators, teachers, and students.

The quantitative analysis was based on responses from questionnaires used for media and content validation, as well as responses from students and teachers. The content validation instrument assessed aspects such as content feasibility, presentation quality, and language clarity. The item validation instrument evaluated aspects including clarity, accuracy of the main idea, relevance, content validity, neutrality, and language precision. The media validation instrument included aspects of graphics and presentation. Respondents consisted of one biology teacher and

26 students from second grade-Class XI IPA 2, who provided feedback on the feasibility, practicality, and effectiveness of the digital student worksheets in fostering critical thinking skills. All questionnaires used a Likert scale with the following response options: very good, good, fair, and poor, to facilitate data processing. The aim of the quantitative analysis was to evaluate the feasibility of the scientific approach-based interactive digital student worksheets in supporting biology learning. The Likert scale categories used for analysis are presented in Table 1.

Table 1. Likert Scale Scoring Weight refers to Sugiyono (2019)

Category	Description	Score
SB	Very Good	4
B	Good	3
KB	Fair	2
TB	Poor	1

Validation Data Analysis

The validity of a media product is determined based on the scores given by expert validators (Rifa et al., 2024). The validation conducted across all aspects was assessed by the validators and presented in tabular form, then the average score was calculated using the formula 1 proposed by Riduwan (2012) as follows:

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

Table 2. Validation Questionnaire Interpretation Criteria, Refers to Riduwan (2012)

Percentage (%)	Criteria
81 - 100	Very valid
61 - 80	Valid
41 - 60	Moderately valid
21 - 40	Less valid
0 - 20	Invalid

Practicality Data Analysis

The practicality analysis was conducted based on the response questionnaires from the biology teacher and students refers to Fitrahtunnisa et al., (2021). The data obtained from the student worksheets practicality test were then analyzed using the percentage formula proposed by Purwanto (2011), as follows formula 2. The results obtained were interpreted based on the following criteria on table 3.

$$\text{Practicality} = \frac{\text{Total Score Obtained}}{\text{Maximum Possible Score}} \text{ x } 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Table 3. Practicality Questionnaire Interpretation Criteria Refers to Riduwan (2012)

Percentage (%)	Criteria
0 - 25	Impractical
26 - 50	Less Practical
51 - 60	Moderately Practical
61 - 80	Practical
81 - 100	Highly Practical

Effectiveness Analysis

The effectiveness of the student worksheets was assessed based on the students' pre-test and post-test results. If the post-test score is higher than the pre-test score, this indicates that the student worksheets is considered effective (Akmala et al., 2023). The improvement in students' learning outcomes through the use of the interactive digital student worksheets based on the scientific approach was measured using the N-Gain score. The N-Gain formula is used to determine the increase in students' learning outcomes by calculating the difference between the pre-test and post-test scores, normalized to the maximum score. This calculation refers to the formula 3 proposed by Hake (1998), as follows:

$$\text{N} - \text{Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Table 4. Gain Normality Criteria Refers to Riduwan (2012)

Normality value	Precentage Range	Description
N-Gain $\geq$ 0.7	High	Effective
0.3 $\leq$ N-Gain < 0.7	Moderate	Moderately Effective
N-Gain < 0.3	Low	Less Affective

RESULTS AND DISCUSSION

The present study is classified as a development research project, which aimed to produce an interactive digital student worksheet. The development of the digital student worksheets was supported by the Liveworksheets platform, which allows users to create or access electronic worksheets for students (Sari et al., 2023). This study was conducted at SMA Swasta Sinar Husni in the XI IPA 2 class and employed the ADDIE development model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation (Wahono et al., 2022).

The digital student worksheets was designed to align with 21st-century learning trends, particularly emphasizing the integration of modern technology, as it can be accessed online. The display of the digital student worksheets can be adjusted in size (zoomed in or out) according to user needs, and it includes instructional videos sourced from YouTube to facilitate students' understanding of the human respiratory system. The development of the student worksheets was also aligned with the phases of the scientific approach, with each stage oriented toward fostering

students' critical thinking skills. These skills, specifically interpretation, analysis, and explanation, were embedded within the student worksheets activities.

Analysis Stage

In the first stage, a needs analysis was conducted for both biology teachers and students.

Biology Teacher Needs Analysis

The analysis of biology teacher needs was conducted by distributing a needs assessment questionnaire to the biology teacher of second grade-class XI IPA 2 and conducting an interview. The student needs analysis was carried out through the distribution of a student needs assessment questionnaire. Findings from the interview with the biology teacher of second grade-class XI IPA 2 revealed that teachers primarily rely on government-issued textbooks as the main source of instructional material provided by the school.

Furthermore, students critical thinking skills remain relatively low, as they are more accustomed to memorizing subject matter to achieve high test scores rather than understanding and exploring the meaning of the content. This habit hinders students from actively developing their cognitive abilities to generate critical and contextually relevant ideas. One contributing factor to this condition is the limited availability of learning resources, as the learning process tends to be centered solely around the textbook provided by the school.

The lack of alternative instructional materials has made it difficult for students to grasp the subject matter in depth. In addition, the teaching methods commonly employed in the classroom remain conventional, such as limited discussions and routine problem-solving exercises. These activities tend to focus on assessing content recall rather than fostering students' critical thinking skills. As a result, students become passive, less motivated, and are not encouraged to engage actively in meaningful learning experiences.

Student Needs Analysis

Referring to the data from the student needs analysis questionnaire, it was found that students experienced difficulties in understanding the topic of the human respiratory system. This was partly due to the lack of variation in both instructional media and teaching methods used by the teacher, indicating a strong need for innovation in both aspects. The questionnaire data also revealed that the integration of technology-based media, including Android devices, had not yet been implemented in the learning process. This highlights the urgency of developing media that utilizes advancements in information and communication technology, particularly Android-based tools, given that the majority of students now own such devices, which can support access to learning resources from various locations.

Design Stage

The initial design of the student worksheets was produced during the design

phase. The design phase is the subsequent stage following the completion of the needs analysis process (Kurniawati et al., 2023). This phase includes the scheduling of media development activities, detailed planning of the media specifications to be developed, preparation of learning materials aligned with the Biology Textbook for Grade XI based on the 2013 Curriculum, and the creation of a storyboard. The media developed specifications are as follows:

1) The development of the media was supported by the *Canva* application.
2) The content focus of this digital student worksheets is the human respiratory system, adapted from the Grade XI biology textbook based on the 2013 curriculum.
3) The developed product contains subject material, texts, illustrations, video recordings, and various exercises in the form of multiple-choice, drag-and-drop, and essay questions.
4) The final product is accessible via smartphones or Android devices.
5) After determining the media specifications, a storyboard was created to assist the researcher in designing the concept and layout of the digital student worksheets to be developed.

Development Stage

The validation results of the interactive digital student worksheets based on the scientific approach indicate that the product falls into the "highly valid" category across all aspects.

Media Validation Results

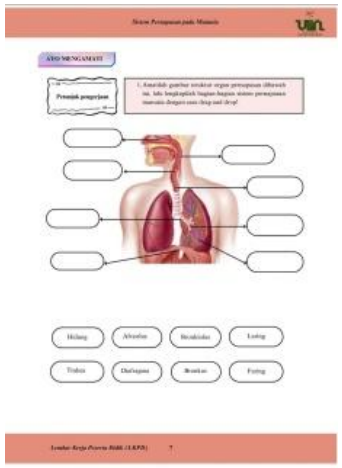
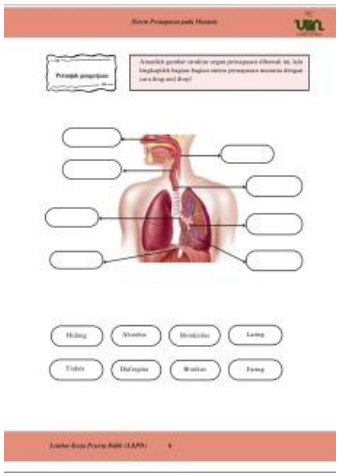
The interactive digital student worksheets was validated by a media expert to ensure its level of validity. The following is a comparison of the media display before and after revision on table 6. Overall, the validators' feedback emphasized the importance of aligning instructional content with the visual elements used in the learning media. This alignment is intended to help students maintain focus, enhance their understanding of the material, and avoid confusion caused by irrelevant or purely decorative images.

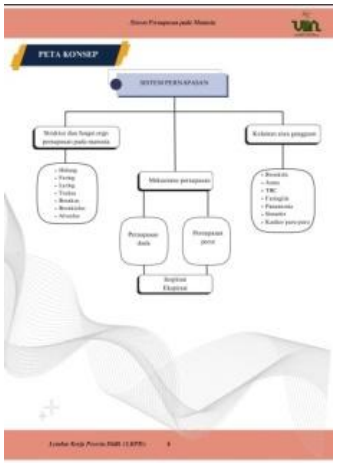
Table 5. Media Validation Data

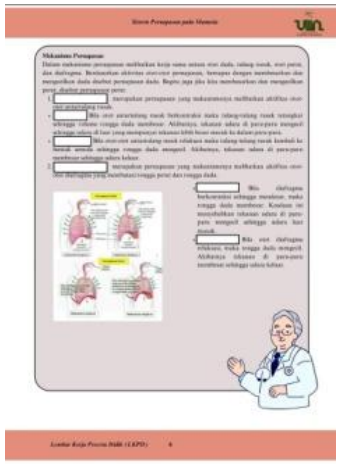
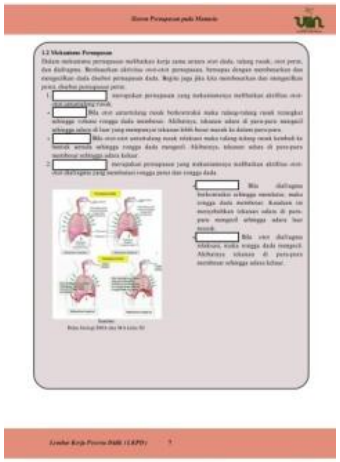
Aspect	Score	Max Score	Percentage (%)	Category
Graphics	35	40	87.50	Very Valid
Presentation	18	20	85.00	Very Valid
Total	**53**	**60**	**88.33**	**Very Valid**

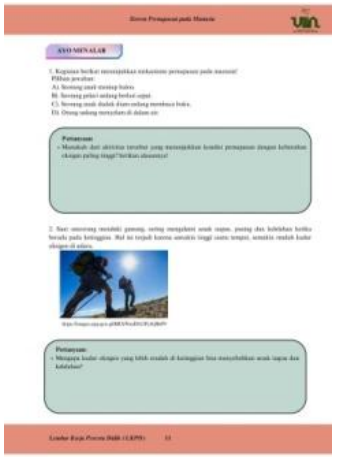
Based on Table 5, validity was evaluated according to two aspects i.e graphics and presentation. The scores obtained were 35 for the graphics aspect and 18 for presentation, resulting in a total score of 53 out of a maximum of 60. This corresponds to a percentage of 88.33 %, which is classified as "very valid." According to the validators' assessment, the interactive digital student worksheets is considered highly feasible in terms of media quality.

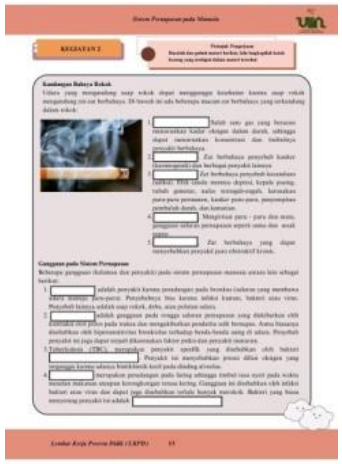
Table 6. Media Display Before and After Revision

No	Media Display Before Revision	Media Display After Revision	Description
1			The validator recommended that the image in the upper corner be replaced with an image of the human respiratory organs only.
2			In the media prior to revision, the organ image was placed in Activity 1 after the material on the mechanism of breathing. The validator recommended that the organ image be placed after the material on the structure and function of the human respiratory organs.

No	Media Display Before Revision	Media Display After Revision	Description
3			The validator recommended that cartoon images unrelated to the material, such as small cloud illustrations and the cartoon doctor image at the bottom, should be removed to avoid creating misleading perceptions for students.
4			The validator recommended that the subheading on the dangers of smoking be combined with the subheading on respiratory disorders. In addition, the cartoon and book images at the bottom should be removed, as they are not relevant to the material and may cause confusion among students.

No	Media Display Before Revision	Media Display After Revision	Description
5			Prior to revision, there was a cartoon doctor image at the bottom of the page. The validator recommended that the cartoon doctor image be removed, as it was not aligned with the instructional content.
6			Prior to revision, there were no activity illustrations in the experiment section, specifically in the procedural steps. The validator recommended adding simple activity images, such as a person sitting calmly and a person jumping, to help students follow the procedures more effectively.

No	Media Display Before Revision	Media Display After Revision	Description
			Prior to revision, there were no activity illustrations in the experiment section, specifically in the procedural steps. The validator recommended adding simple activity images, such as a person sitting calmly and a person jumping, to help students follow the procedures more effectively.
7			In the pre-revision version of the media, there were images of a child blowing a balloon, a runner, a child sitting still, and a person diving underwater. The validator recommended that these images be removed, as they were presented in the form of illustrations rather than scientifically accurate visuals.

No	Media Display Before Revision	Media Display After Revision	Description
8			In the pre-revision version of the media, there was an image of a cigarette along with a subtopic on the dangers of smoking. The validator recommended that the subtopic on the dangers of smoking be integrated with the subtopic on respiratory disorders.

This high level of validity indicates that the media was well-designed both visually and in terms of presentation, making it effective in capturing students' attention and facilitating active learning processes. The media's feasibility serves as a critical foundation for achieving the goal of enhancing students' critical thinking skills, as valid and effective media can assist students in developing higher-order thinking abilities such as analysis, evaluation, and independent problem-solving (Nurhayati & Lestari, 2022). In addition to providing judgments on feasibility, the media expert also offered feedback and recommendations for improving the developed media. These findings are in line with the study by Ghozali & Zulfah (2023), which examined the validity of interactive learning media, including expert validation procedures, suggestions for improvement, and their application in enhancing learning quality.

Content Validation Results

Based on the analysis of Table 7, the validity was assessed across three aspects: content feasibility (score = 25), presentation (score = 6), and language (score = 11). The total score obtained was 42 out of a maximum of 48, resulting in a percentage of 87.5%, which falls into the "very valid" category. This indicates that the student worksheets is suitable for implementation, in accordance with the recommendations and feedback from the validators. Among the suggestions was the correction of typographical errors in the material to ensure that content presentation is free from misconceptions that could hinder students' knowledge acquisition.

Table 7. Content Validation Data

Aspect	Score	Max Score	Precentage	Category
Content Feasibility	25	28	89%	Very Valid
Presentation	6	8	75%	Valid
Language	11	12	91.6%	Very Valid
Total	**42**	**48**	**87.5%**	**Very Valid**

This finding is consistent with the study by Sarah et al., (2022), which reported that student worksheets materials developed using Liveworksheets were rated as "very valid" by experts. Similarly, research by Kurniawati et al., (2023) showed that discovery learning-based student worksheets also received a high validity rating and emphasized the importance of minimizing conceptual errors that could mislead students similar to the current study's finding regarding the need to correct typos to prevent misconceptions. Thus, the material validation results in this study are supported by empirical evidence from related research, reinforcing the conclusion that the scientific approach-based interactive digital student worksheets has strong potential to support meaningful learning processes.

Assesment Item Validation Results

Referring to the findings presented in Table 8, the item validation data indicate that the validity assessment was conducted across six aspects: clarity (score = 8), accuracy of the main idea (score = 3), relevance (score = 4), content validity (score = 4), absence of bias (score = 3), and language accuracy (score = 13). The total score obtained was 35 out of a maximum of 40, resulting in a percentage of 87.5%. Feedback from the validator included recommendations that each question at the senior high school level should provide five answer options and that the distribution of the test items should be normal. This high score indicates that the test items fall under the "very valid" category and are highly appropriate to be used as evaluation instruments within the scientific approach-based interactive digital student worksheets.

Table 8. Assesment Item Validation Data

Aspect	Score	Max Score	Percentage (%)	Category
Clarity	8	8	100	Very Valid
Core Accuracy	3	4	75.00	Valid
Relevance	4	4	100	Very Valid
Content Validity	4	4	100	Very Valid
Absence of Bias	3	4	75.00	Valid
Linguistic Accuracy	13	16	81.25	Very Valid
Total	**35**	**40**	**87.50**	**Very Valid**

These findings are consistent with the study by Wahono et al., (2022), which also demonstrated that evaluation questions developed within a scientific approach-based e-worksheets exhibit a high degree of validity and are appropriate for use in science learning activities. Thus, the item validation results in this study reinforce the conclusion that the development of a scientific approach-based interactive digital student worksheets has significant potential to support effective, relevant, and 21st-century-oriented learning evaluation.

Implementation Stage

In the implementation phase, a practicality test was conducted after the product had been validated by experts (Yuliana & Mulyani, 2024). The practicality test aimed to determine the extent to which the developed scientific approach-based interactive digital student worksheets could be used easily and effectively by both teachers and students throughout the learning process (Fitrahtunnisa et al., 2021).

Table 9. Student Response Data on the Learning Media

Aspect	Score	Max Score	Precentage (%)	Category
Content	468	520	90.00	Very Valid
Visual design	399	416	96.00	Very Valid
Learning activity	180	208	86.50	Very Valid
Total	**1.047**	**1.144**	**92.00**	**Very Valid**

Table 10. Teacher Response Data on the Learning Media

Aspect	Score	Max Score	Precentage (%)	Category
Content	19	20	95.00	Very Valid
Visual design	15	16	93.75	Very Valid
Learning activity	7	8	87.50	Very Valid
Total	**41**	**44**	**93.00**	**Very Valid**

Based on Table 9, the practicality test results were obtained from student response questionnaires involving 26 participants. The questionnaire consisted of three assessment aspects: content, which received a score of 468; visual design, which scored 399; and learning activities, which scored 180. The total score obtained was 1,047 out of a maximum of 1144, resulting in a percentage of 92 %. This high score indicates that the scientific approach-based interactive digital student worksheets is

considered highly practical for use by both students and educators. The high percentage of student responses reflects strong interest and engagement in the worksheets activities. The digital student worksheets was regarded as attractive, easy to use, and supportive of active student participation. As a result, students were less likely to feel bored during the learning process and found the material easier to comprehend.

Table 10 presents the results of the teacher response questionnaire, which also assessed three aspects: content (score = 19), visual design (score = 15), and learning activities (score = 7). The total score achieved was 41 out of a maximum of 44, yielding a percentage of 93%, which falls into the "very practical" category. This finding confirms that, from the teacher's perspective, the media is highly suitable for classroom learning activities. The developed student worksheets fulfilled criteria such as ease of use, clarity of instructions, and comprehensibility of content. These results also demonstrate that the student worksheets is easily integrated into classroom instruction and promotes active learning aligned with the scientific approach. This finding is consistent with Septiani et al., (2022) research indicating that interactive learning media that incorporate digital technology and the scientific approach can enhance student engagement, usability, and content understanding.

Evaluation Stage

The improvement in students' critical thinking skills regarding the topic of the human respiratory system was evaluated using the N-Gain test, calculated by measuring the difference between the pre-test and post-test scores. The average pre-test score was 47, while the post-test average increased to 86.23. After using the scientific approach-based digital student worksheets, the gain between pre- and post-test scores was 39.34. The resulting N-Gain score was 0.76, which falls within the "high" category, indicating that the intervention was effective in enhancing students' critical thinking abilities.

Table 11. Effectiveness Test Results Based on N-Gain

Average pretest score	Average postest score	Postest-pretest	Max Score	Max Score-pretest	N-Gain score	N-Gain (%)	Criteria
47	86.23	39.34	100	53.11	0.76	76.70	Effective

Pedagogically, the high N-Gain score suggests that the use of scientific approach-based interactive digital student worksheets significantly contributed to improving the quality of the learning process. This demonstrates that students experienced not only cognitive improvement but also enhancement of higher-order thinking skills, particularly critical thinking. The scientific approach implemented in the worksheets guided students through key stages such as observing, questioning, exploring, reasoning, and communicating results activities that are closely aligned with constructivist learning principles. Consequently, the learning process became more meaningful and student-centered, fostering the development of analytical and reflective skills necessary for understanding complex concepts like the human

respiratory system. These results underscore the importance of innovative, technology integrated instructional design in improving the effectiveness of 21st-century education.

By applying a scientific approach to the subject matter, students were able to grasp the content more effectively. The digital student worksheets was specifically designed to train critical thinking through scientific stages that required students to observe real-life phenomena, generate inquiry-based questions, conduct independent exploration and data collection, reason based on findings, and communicate conclusions. These stages not only promoted critical thinking but also supported academic achievement throughout the learning process. Furthermore, the use of contextualized questions, problem-based activities, and interactive media helped students become more active and engaged, and allowed them to relate classroom content to real-world situations thereby optimizing the development of critical thinking skills.

The digital student worksheets developed in this study serves as a practical learning tool, particularly for the topic of the human respiratory system in biology. The evaluation results confirmed that the worksheets achieved high quality in terms of validity, practicality, and effectiveness. Key advantages of the digital student worksheets include easy access and storage, increased student motivation, paper-saving benefits, and automatic correction features provided by the Liveworksheets platform. However, its limitations include the requirement for smartphones and internet data to access the content. In addition, teachers still need to manually review and grade open-ended responses. These findings are consistent with the study by Sarman et al., (2023), which highlighted that digital student worksheets are easily accessible anytime and anywhere as long as supporting facilities are available and that they can enhance students' independent learning skills. However, if such facilities are lacking, the use of digital worksheets may be constrained.

CONCLUSION

This results indicate that the scientific approach-based interactive digital student worksheets on the human respiratory system is both valid and practical for classroom use, receiving highly positive responses from both teachers and students. These findings demonstrate that the media is effective in supporting the development of students' critical thinking skills through contextual and interactive learning. The primary contribution of this research lies in the development of a digital worksheets that integrates the scientific approach with the Liveworksheets platform, specifically designed for the respiratory system topic an area that has received limited attention in previous studies. However, the implementation of this media remains limited to a specific context; therefore, broader trials are necessary to validate its general effectiveness. As such, the findings of this study cannot yet be generalized to all educational settings. Future research is encouraged to examine the effectiveness of this digital student worksheets on a larger scale and to incorporate more varied automatic assessment features. This study contributes meaningfully to 21st-century learning innovations aimed at strengthening students' critical thinking skills.

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