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Development of an e-worksheet circulation system based on an in-depth learning approach to train higher-order thinking skills of grade XI high school students

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Abstract. Higher Order Thinking Skills (HOTS) is a crucial competency in the 21st century, but students' HOTS abilities in Indonesia have not shown optimal results. In addition, the complex and abstract material of the circulatory system requires teaching materials that can support meaningful learning while training students' HOTS. The need for learning that can train HOTS can be accommodated through the Deep Learning Approach that emphasizes the principles of mindful, meaningful, and joyful learning. This research aims to produce a valid, practical, and effective Circulation System E-Worksheet based on the Deep Learning approach to train HOTS for Grade XI high school students. This research method applies a 4-D model that includes the stages of define, design, develop, and disseminate. The research instruments include a validation sheet, an observation sheet for implementing learning activities, a student response questionnaire, and HOTS test questions. The resulting E-Worksheet then underwent a limited trial on 20 grade XI IPA students of SMAN 16 Surabaya. The parameters of this study include validity based on expert assessment, practicality based on the implementation of learning activities and student responses to using the E-Worksheet, and effectiveness based on students' HOTS achievement. Data were analyzed descriptively and quantitatively using simple statistics, including averages and percentages. The results of the study show that the resulting E-WORKSHEET obtained a validity score of 3.67 (very valid), practicality reviewed from the implementation of learning activities of 100% (very practical) and positive student responses of 99.33% (very practical), and effectiveness based on the achievement of HOTS indicators including analysis, evaluation, and creation respectively of 75%, 80%, and 90%. Thus, the resulting E-Worksheet Circulation System based on the Deep Learning approach is considered valid, practical, and effective for practicing HOTS.
Keywords: Circulation system, Deep learning approach, E-worksheet, Higher-order thinking skills.

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Introduction

21st-century developments emphasize students' mastery of various skills to face global challenges, including Higher Order Thinking Skills (HOTS). HOTS encompasses the ability to analyze, evaluate, and create, which plays a crucial role in developing critical thinking, problem-solving, decision-making, and creative idea generation. These skills align with 21st-century learning needs, which shape learning abilities through the 4Cs (critical thinking, creativity, communication, and collaboration) (The Partnership for 21st Century Learning, 2015). However, students' HOTS skills in Indonesia have not shown optimal results. The 2022 Programme for International Student Assessment (PISA) results revealed that less than 1% of Indonesian students were able to solve problems at Levels 4–6 (OECD, 2023). These findings indicate that the learning process in schools still emphasizes low-level thinking skills and memorizing concepts (Rismana & Hernawati, 2025).

One biology topic that requires HOTS is the circulatory system because it has complex, abstract characteristics and involves the interrelationship of various physiological processes, which can lead to misconceptions (Gafur et al., 2024; Yeşilyurt & Gül, 2012). In the Independent Curriculum, the learning outcomes for the circulatory system require students to analyze the relationship between organ structure and function and disorders that affect the

circulatory system. Therefore, instruction on this material should be designed to stimulate deep cognitive structures and support higher-order thinking skills, not simply memorizing concepts (Al Aliyawinata et al., 2021; Shafira et al., 2022).

One approach that can support HOTS development is the Deep Learning Approach. This approach emphasizes a conscious, meaningful, and enjoyable learning process, enabling students to gain a deep understanding of concepts while simultaneously fostering critical thinking, collaboration, and innovation (Gufron & Suryahadikusumah, 2025; Kementerian Pendidikan Dasar dan Menengah, 2025; Ru, 2024). To implement the principles of the Deep Learning Approach effectively, a learning model is needed to facilitate active student involvement. One relevant model is the cooperative learning model, as it focuses the learning process on students (student-centered) and supports learning through interaction, discussion, and group collaboration (Zhou & Colomer, 2024). The characteristics of this model enable teachers to develop students' learning independence, as well as collaboration, communication, and critical thinking skills that align with the principles of the Deep Learning Approach.

With the development of technology, Electronic Student Worksheets (E-worksheet) have become one of the digital teaching materials that can support interactive and independent learning processes (Safitri et al., 2024). E-worksheet has various advantages that support the implementation of the Deep Learning Approach. Through its interactive and dynamic features, E-worksheet can improve learning outcomes and encourage active student participation during the learning process (Asmaryadi et al., 2022). In addition, E-worksheet is flexible and can be adapted to students' needs and teachers' creativity in designing optimal learning experiences (Istiqomah, 2021).

Integrating the Deep Learning Approach into E-worksheet can facilitate students' exploration of information, problem-solving, and reflection, thereby fostering HOTS. Previous research has shown that implementing the Deep Learning Approach in E-worksheet is valid, practical, and effective in fostering students' HOTS (Lestari & Rakhmawati, 2024). In addition, applying the principles of meaningful learning, joyful learning, and mindful learning can strengthen students' understanding of concepts, analytical skills, and motivation to learn (Firmansah et al., 2024; Pertiwi et al., 2020; Rahma & Kusumawardani, 2022). However, research integrating the Deep Learning Approach into the design of an e-worksheet on circulatory system material remains limited.

Based on this description, this study aims to produce an E-worksheet on the circulatory system material using the Deep Learning Approach that is valid, practical, and effective for training HOTS for grade XI high school students. This E-worksheet can serve as an alternative digital teaching material that supports the implementation of the Deep Learning Approach while strengthening HOTS-oriented biology learning.

METHOD

Research Design

This research applies the 4-D development model designed by Thiagarajan et al. (1974). It includes the define, design, develop, and disseminate stages. One advantage of the 4-D model is that it provides systematic, comprehensive stages, allowing the E-worksheet development procedure to be implemented in a more focused and easily controlled manner (Waruwu, 2024). The define stage focused on analyzing the curriculum, students, assignments, concepts, and designing learning objectives. The design stage involved drafting the format and features of the E-worksheet and developing research instruments. The development stage involved expert validation, product revisions, and limited student trials. The dissemination stage involved publishing the research results. The research targets included the E-worksheet, which was developed and piloted with 20 11th-grade students as product users.

Research Instrument and Data Collection Technique

The research instruments included a validation sheet, an observation sheet for implementing learning activities, a student response questionnaire, and HOTS test items. The validation sheet assessed the validity of the E-worksheet, which consisted of 10 assessment items for the main components of the presentation aspect, 4 assessment items for the main components of the content aspect, and 2 assessment items for the main components of the language aspect. The validity assessment involved two lecturers acting as validators: media experts and material experts. The observation sheet assessed the implementation of student learning activities during the use of the E-worksheet, which consisted of 11 student activity items. Three observers conducted the implementation assessment. A student response questionnaire was used to obtain student responses regarding the implementation of the E-worksheet in terms of presentation (5 items), content (9 items), and language (2 items). HOTS test questions were used to assess students' achievement of higher-order thinking skills, including analytical competencies (C4), evaluation (C5), and creativity (C6). The questions consisted of 10 items: three Lower Order Thinking Skills (LOTS) level questions and seven HOTS level questions. The resulting E-worksheet was compiled using the Canva platform and then converted via the Liveworksheets page so that students could access learning activities independently through electronic devices such as laptops or gadgets.

Data Analysis

The research data were analyzed descriptively and quantitatively. The validity of the E-worksheet was assessed based on the average validation score using a 4-point Likert scale, 1-4 (poor to very good) and interpreted according to the validity criteria (1.00-1.74 = invalid; 1.75-2.49 = less valid; 2.50-3.24 = valid; 3.25-4.00 = very valid). The E-worksheet was declared valid if the validity score reached ≥2.50 (Upara & Chusanachoti, 2023). The practicality of the E-worksheet was analyzed based on the percentage of learning activity implementation and positive student responses to its use. The results of implementation and student responses were determined based on observer observations of student activities using the Guttman scale, namely Yes (1) and No (0). The results of observations and positive student responses were then interpreted as a percentage according to the practicality criteria (0-50 = not practical, 51-70 = less practical, 71-85 = practical, 86-100 = very practical). The e-worksheet was declared practical if each implementation result and positive student response scored≥71% (Akbar, 2013). The effectiveness of the e-worksheet was analyzed based on students' HOTS achievement through HOTS test results, which include analysis, evaluation, and creativity indicators. HOTS test results are presented as scores categorized according to Fausan et al. (2021): 0-54 (very low), 55-59 (low), 60-75 (sufficient), 76-85 (good), 86-100 (very good). The e-worksheet is considered effective if the percentage of students achieving scores in the good-to-very-good range reaches ≥71% (Akbar, 2013).

RESULTS AND DISCUSSION

This research creates a Circulatory System e-worksheet based on the Deep Learning approach to train HOTS for grade XI high school students. The e-worksheet product consists of two discussion topics: e-worksheet Topic 1 and e-worksheet Topic 2. Topic 1 contains the material "Structure and Function of Circulatory System Organs" while Topic 2 contains the material "Blood Components and Diseases or Disorders of the Circulatory System". Figure 1 shows the designed e-worksheet profile.

a) b) c)

Figure 1. E-worksheet sections a) main cover page; (b) E-worksheet introduction; (c) Activity page

The learning activities in each e-worksheet feature are aligned with the principles of Deep Learning, namely meaningful, enjoyable, and conscious, as well as learning experiences, namely understanding, applying, and reflecting, to train HOTS, which includes analysis, evaluation, and creation. This e-worksheet also includes the features described in Table 1.

Table 1. Description of circulation system e-worksheet features

E-worksheet Features	Description
Let's Get To Know! 	This feature encourages students to identify the parts of the organs or components of the circulatory system and their functions through reading materials and other sources, such as links or QR codes.
Let's Try! 	This feature encourages students to directly apply their knowledge through simple experiments or virtual labs, such as measuring blood pressure using a digital sphygmomanometer in Topic 1 and identifying blood types using the VLab Blood Type application in Topic 2.
Let's Analyze! 	This feature encourages students to analyze information, such as interpreting data and providing solutions to problems through simple case studies.
Let's Evaluate! 	This feature encourages students to review information and express opinions through evaluation, including providing suggestions, assessments, and justification for the information presented in the learning activities.
Let's Create! 	This feature encourages students to design plans and products through creativity, such as lifestyle planning and poster creation as a campaign to prevent circulatory system diseases.

E-worksheet Validity

The e-worksheet validation included three assessment aspects: presentation, content, and language. The presentation, content, and language aspects received average scores of 3.82, 3.53, and 3.67, respectively. The overall average score for the three assessment aspects was 3.67, meeting the very valid criteria. These results demonstrate that the resulting e-worksheet is suitable for implementation in the learning process. Table 2 presents the validity results.

The presentation aspect achieved the highest average score of 3.82, with the criteria of very valid. These results indicate that the e-worksheet display has been designed in an attractive, structured, and user-friendly manner for students. The proportional layout, representative image quality, and multimedia design through links and QR codes support interactive and flexible digital learning. This aligns with Singh & Morkel (2024), which confirms that attractive teaching materials that capture initial attention can foster interest and increase learning involvement.

Table 2. Results of the e-worksheetvalidity assessment by experts (n=2)

No.	Rated aspect	Average
A. Presentation aspects		
1	E-worksheet cover design	3.67
2	E-worksheet title	3.83
3	Time allocation	4.00
4	Learning objectives	3.67
5	E-worksheet user guide	3.50
6	E-worksheet presentation system	3.33
7	E-worksheet page layout	3.83
8	Image quality	4.00
9	E-worksheet features	3.50
10	E-worksheet accessibility	3.67
	Average Presentation Aspect	**3.82**
	Interpretation	**Very Valid**
B. Content aspects		
11	Alignment of material with concept	4.00
12	Alignment of e-worksheets with deep learning approach principles	3.50
13	Alignment of e-worksheets with deep learning experiences	3.50
14	Alignment of e-worksheets for training higher-order thinking skills (HOTS)	3.17
	Average Content Aspect	**3.53**
	Interpretation	**Very Valid**
C. Linguistic aspects		
15	Language Use	3.50
16	Sentence Conformity with General Indonesian Spelling Guidelines	3.83
	Average Linguistic Aspect	**3.67**
	Interpretation	**Very Valid**
	Overall Average of Assessment Aspects	**3.67**
	Interpretation of E-WORKSHEET Validity	**Very Valid**

In terms of presentation, several components received additional comments from the validator, such as the formulation of learning objectives using an operational structure (audience, behavior, condition, and degree), the e-worksheet presentation system, and the feature for sending answers directly to teachers. These components still require refinement, particularly adjusting the learning objective structure and optimizing the interactive features on the digital platform. Nevertheless, these components remain valid and are still suitable for use after revisions based on the validator's suggestions.

The content aspect received an average score of 3.53, categorized as very valid. This demonstrates that the circulatory system material presented is appropriate and structured based on the Biology learning outcomes of Phase F of the Independent Curriculum. Alignment of the material with the concepts is crucial to enable students to construct a comprehensive and systematic conceptual understanding (Vincent, 2015).

In assessing the e-worksheet's suitability with the principles of the Deep Learning approach, several indicators received additional input from the validator, particularly on the principles of meaningful learning and mindful learning. The validator assessed that the learning activities in the e-worksheet helped students discover relationships between new concepts and previous experiences or knowledge and learn contextually, although the implementation could still be developed more deeply. Contextual learning is important in the Deep Learning approach because it helps students understand the material's relevance to life (Ausubel, 1963; Feriyanto & Anjariyah, 2024). Furthermore, the reflection and planning components in the Let's

Evaluate! and Let's Create! features also require refinement, as students' reflective activities could be strengthened. However, integrating the principles of meaningful, joyful, and mindful learning within e-worksheet aligns with the characteristics of the Deep Learning approach, which emphasizes meaningful, joyful, and conscious learning.

Regarding the suitability of e-worksheet for Deep Learning experiences, the Let's Get To Know! and Let's Try! features were deemed appropriate for the understanding stage, while the Let's Analyze! feature was deemed appropriate for the application stage. The Let's Evaluate! and Let's Create! features received a score of 3 for the reflection stage. These results indicate that the learning activities in e-worksheet can accommodate students' continuous learning experiences, from understanding concepts and applying knowledge to reflecting on learning outcomes. This aligns with constructivism theory, which explains that knowledge is constructed through active and reflective participation throughout the learning process.

The e-worksheet's suitability for HOTS training also met the validity criteria with an average score of 3.17. The "Let's Analyze!" feature was deemed appropriate for training analytical skills (C4), while the "Let's Evaluate!" and "Let's Create!" features for training evaluation (C5) and creativity (C6) still needed improvement. These results show that the designed learning activities focus on training higher-order thinking skills, although the evaluation and creativity aspects could be further developed to provide optimal HOTS stimulation.

The linguistic aspect achieved an average score of 3.67, with very valid criteria. The validation results demonstrated that the sentences used in the e-worksheet were straightforward, communicative, easy to understand, and free from multiple interpretations. Furthermore, the use of italics for foreign terms and the use of punctuation were deemed appropriate. Clear, communicative language is important in teaching materials because it supports students' independent analysis of instructions and learning materials. In learning Biology, appropriate scientific terms are important so students understand concepts correctly, but these terms must also be conveyed with simple explanations so they are not ambiguous and do not invite different interpretations (Fujita & Cunnings, 2020). Using standard sentences is also important to maintain the academic quality of teaching materials and make it easier for students to understand the information correctly (Cheng, 2021; Hackemann et al., 2022).

Overall, the validation results indicate that the designed e-worksheet met the validity criteria in terms of presentation, content, and language. The revision process, based on the validator's recommendations and comments, also helped improve the product's quality, making the e-worksheet suitable for implementation in biology learning and HOTS training for eleventh-grade high school students.

Practicality of E-worksheet

The practicality of the Circulation System e-worksheet based on the Deep Learning approach was evaluated by reviewing the implementation of learning activities and student responses to using the e-worksheet. The results showed that the e-worksheet met the criteria of being very practical based on both indicators.

Observations of the implementation of learning activities showed that all learning activities using the e-worksheet were implemented at 100% in Topic 1 and Topic 2, meeting the criteria of being very practical. This shows that students can implement all learning stages in the e-worksheet optimally, without significant obstacles. These results align with research by Chisunum & Nwadiokwu (2024), which confirms that highly practical teaching materials can support the optimization of student learning activities. Table 3 presents data from observations of the e-worksheet implementation.

The high level of learning activity implementation is also influenced by the integration of learning features in the e-worksheet, which is designed using a Deep Learning approach.

The Let's Try! feature provides an active learning experience through simple experiments and virtual practicums. In this feature, observers noted increased student enthusiasm during experiments, shown through high participation and interest in comparing results among group members. This result aligns with the principle of joyful learning in the Deep Learning approach, which emphasizes creating a fun, challenging learning experience and helps students stay active in the learning process. In addition, research by Teplá & Distler (2025) also emphasized that an experience-based learning process can optimize student involvement, motivation, and enthusiasm in science learning.

Furthermore, as a primary focus of HOTS training, analytical skills are developed through the Let's Analyze! feature, which guides students to actively process and connect information to build deeper understanding. This aligns with the process skills element of Biology Learning Outcome Phase F, namely processing and analyzing data and information.

Evaluation skills are practiced through the Let's Evaluate! feature, such as providing healthy lifestyle suggestions and justifying statements. Furthermore, researchers found that students could formulate questions to identify the relationship between peers' lifestyles and blood pressure measurement results, which were previously conducted during the interview activity in the Let's Evaluate! Topic 1 feature. Students then interpreted the interview results to assess circulatory system health risks and recommend preventive measures. This activity aligns with the evaluation indicators because it requires students to make judgments based on scientific facts and criteria, compare information, and formulate logical and relevant recommendations. This also reinforces the principles of mindful learning and reflective learning experiences in the Deep Learning approach, as students are directed to consciously evaluate daily habits and relate them to their health conditions. These findings align with Murtonen & Balloo (2019), which states that evaluation activities encourage students to use the knowledge they have to make logical considerations based on scientific data, as well as Bordunos et al. (2024), which states that mindful learning requires students to reflect on learning experiences and build a more flexible and open understanding of various perspectives.

Meanwhile, creative skills are honed through the Let's Create! feature, which involves planning lifestyle changes and creating creative posters as an awareness campaign about circulatory health. This aligns with Alkhatib's (2019) framework, which emphasizes developing creative abilities by training students through contextual, problem-based creative activities, as students are guided to make decisions and produce new solutions to problems.

The practicality of the e-worksheet was also assessed based on student responses regarding its use. The average responses for the presentation, content, and language aspects were 98%, 100%, and 100%, respectively, with the criteria being very practical. The overall average score was 99.33%, with the criteria being very practical. The student responses are presented in Table 4.

In terms of presentation, students responded positively, with an average of 100% (very practical). A 5% negative response was obtained for the font type and size and time allocation components. This may be because students did not enlarge the screen display, resulting in unclear words or sentences. Furthermore, devices such as gadgets/cellphones with small screens prevent students from clearly viewing sentences without enlarging the display on the Liveworksheets page. Meanwhile, the font type and size component in the validity assessment received very valid criteria.

Table 3. Results of the implementation of e-worksheet learning activities (n=20)

No	Student Activities	E-worksheet Implementation (%)			
		E-worksheet Topic 1		E-worksheet Topic 2	
		Implemented	Not Implemented	Implemented	Not Implemented
1	Operate the e-worksheet online properly (no significant issues)	100	0	100	0
2	Read the learning objectives contained in the e-worksheet	100	0	100	0
3	Read the instructions contained in the e-worksheet	100	0	100	0
4	Access the links and QR codes provided in the e-worksheet	100	0	100	0
5	Read and listen to information in the form of text or videos in the Let's Get To Know! feature Principles of Deep Learning: meaningful learning Learning Experience: Understanding	100	0	100	0
7	Conduct experiments according to the instructions in the "Let's Try!" feature. Deep Learning Principle: Joyful Learning Learning Experience: Understanding and Applying	100	0	100	0
8	Analyze data based on the information/data obtained in the Let's Analyze! feature. HOTS: Analysis (C4) Deep Learning Principles: Joyful & Meaningful Learning Learning Experience: Applying	100	0	100	0
9	Evaluate and actively provide suggestions based on the information/data obtained in the Let's Evaluate! feature. HOTS: Evaluation (C5) Deep Learning Principle: Mindful Learning Learning Experience: Reflection	100	0	100	0
10	Planning and creating work based on information/data obtained through the Let's Create! feature. HOTS: Creating (C6) Deep Learning Principle: Mindful Learning Learning Experience: Reflecting	100	0	100	0
11	Submit your answers to get feedback from your teacher.	100	0	100	0
12	Complete the activities in the e-worksheet feature sequentially according to the stages.	100	0	100	0
	Average Implementation (%)	**100**		**100**	
	Overall Average (%)	**100**			
	Interpretation of E-WORKSHEET Implementation	**Very Practical**			

Table 4. Results of student responses to e-worksheet(n=20)

No.	Assessment Aspects	Response (%)	
		Yes	No
A.	**Presentation aspects**		
1	The e-worksheet cover design is attractive.	100	0
2	The e-worksheet font type and size are easy to read.	95	5
3	The e-worksheet's appearance and layout are neat.	100	0
4	Multimedia (QR codes, links, videos) are easily accessible.	100	0
5	The time allocation aligns with the learning activities.	95	5
	Average Presentation Aspect (%)	**98**	
	Interpretation	**Very Practical**	
B.	**Content aspects**		
6	E-worksheet facilitates understanding and mastery of concepts.	100	0
7	The Let's Get To Know! feature helps students understand basic material on the circulatory system, such as the structure/arrangement of blood cells and blood vessels.	100	0
8	The Let's Try! feature helps students better understand the material through experiments with blood pressure measurements and blood type tests.	100	0
9	The Let's Analyze! feature guides students in identifying relationships between concepts, analyzing cases, and interpreting information in the circulatory system material.	100	0
10	The Let's Evaluate! feature trains students in providing assessments/justifications, suggestions, and solutions to problems related to the circulatory system.	100	0
11	The Let's Create! feature helps students plan and implement a lifestyle that maintains a healthy circulatory system in their daily lives.	100	0
12	The e-worksheet helps students see the relationship or interconnection between circulatory system material, their personal lifestyle, and the surrounding environment. The Deep Learning Principle: Meaningful	100	0
13	E-worksheet increases students' motivation and interest in learning. The Deep Learning Principle: Enjoyable	100	0
14	The e-worksheet encourages students to reflect on their lifestyle and understand its impact on circulatory system health. The Deep Learning principle: be conscious	100	0
	Average content aspect (%)	**100**	
	Interpretation	**Very Practical**	
C.	**Linguistic aspects**		
15	The language used is easy to understand.	100	0
16	The sentences used are unambiguous.	100	0
	Average Language Aspect (%)	**100**	
	Interpretation	**Very Practical**	
	Average Overall Assessment Aspect (%)	**99,33**	
	Interpretation of Student Responses	**Very Practical**	

In terms of content, students stated that the e-worksheethelped them understand the concept of the circulatory system and trained their HOTS skills through the Let's Analyze!, Let's Evaluate!, and Let's Create! features. Learning activities in the e-worksheet were assessed as helping students think critically, analyze problems, provide solutions, and generate creative ideas related to circulatory system health. These results indicate that students have developed a strong understanding of the concept and can integrate the material with real-world applications through contextual learning activities. This aligns with Rahayu & Alsulami (2024), which explains that HOTS-based learning helps students think reflectively, analyze information, and make critical decisions in the problem-solving process.

Students also responded positively to the language aspects of the e-worksheet. The language used was considered communicative, easy to understand, and free from ambiguity.

Clear language is crucial in digital learning materials because it helps students understand instructions and learning concepts independently (Botha et al., 2025). This also supports the previous linguistic validity results, which showed that the e-worksheet met the criteria for good linguistics according to correct writing standards.

Overall, the results of the implementation of learning activities and student responses indicate that the Circulation System e-worksheet, based on the Deep Learning approach, has a very high level of practicality. The integration of HOTS-based learning features, interactive multimedia, and the principles of meaningful, enjoyable, and mindful learning makes the e-worksheet easy to use and helps create an active, contextual, and enjoyable learning environment for students.

Effectiveness of E-worksheet

The effectiveness of the e-worksheet Circulation System based on the Deep Learning approach is reviewed through students' HOTS achievement, including analysis (C4), evaluation (C5), and creation (C6) competencies. The HOTS indicator achievement results for all students were 75%, 80%, and 90% for analysis, evaluation, and creation, respectively. Figure 1 presents students' HOTS achievement results.

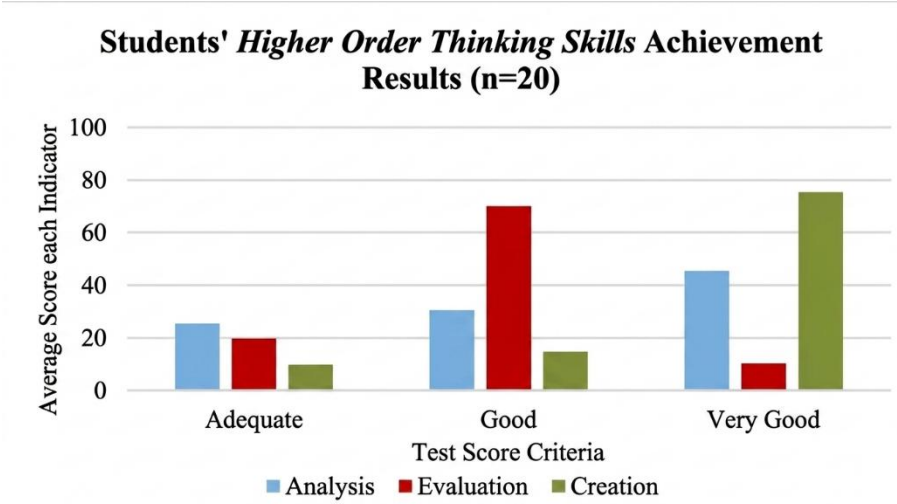

Figure 1. Distribution of HOTS Achievement Results of Students

In the analytical skills indicator (C4), 75% of students were in the good to very good category, while 25% were still in the adequate category. These results indicate that most students could identify relationships between concepts, interpret data, and analyze problems related to the circulatory system. Activities in the Let's Analyze! feature, which included activities such as interpreting blood pressure data, analyzing the relationship between the structure and function of circulatory system organs, and analyzing factors causing circulatory system disorders. These contextual learning activities help students build a more comprehensive understanding because they not only digest information but also process and connect new information (Silalahi et al., 2022).

Although the analysis indicators were categorized as good, some students still faced obstacles in connecting various concepts of the circulatory system simultaneously. This may be because analytical skills require complex thinking processes and the ability to connect various concepts simultaneously. According to Facione (2015), Analytical skills are characterized by the ability to accurately identify relationships between information, concepts, statements, or opinions. However, the average score in the good category, with more than 71% of students achieving good to excellent scores on the analysis indicator, indicates that the e-

worksheet has helped most students develop their analytical skills optimally.

For the evaluation skills indicator (C5), the average student score reached 80.25, categorized as good. Eighty percent of students were in the good to excellent category, while the remaining 20% were in the fair category. Students practiced evaluation skills through the "Let's Evaluate!" feature, which included activities such as providing healthy lifestyle advice, evaluating the causes of circulatory system disorders, and providing solutions to health case studies. These activities helped students think reflectively and logically when making decisions. Although the evaluation indicator achieved a good score, it had the lowest average score among the HOTS indicators. This indicates that evaluation skills remain a barrier for some students because they require justification and consideration based on strong scientific reasoning. Students are not only asked to digest concepts but also to assess, consider, and provide logical solutions to problems (Facione, 2015). This skill requires more in-depth reflective thinking practice, so some students still struggle to provide complete and accurate arguments.

The creativity skill indicator (C6) achieved the highest average achievement rate, at 90%, categorized as very good. The results indicate that most students were able to generate ideas, solutions, and creative works based on the concepts they had learned. Students practiced creative skills through the "Let's Create!" feature, which included activities such as developing a healthy lifestyle plan and creating an awareness campaign poster related to circulatory health. These activities gave students opportunities to apply what they learned in concrete ways relevant to their daily lives.

The high achievement rate of the creativity indicator also indicates that students felt freer and more motivated to develop creative ideas when learning was linked to real-life and contextual problems. This aligns with the principles of mindful and joyful learning in the Deep Learning approach. Mindful and enjoyable learning can accelerate student motivation and engagement, making them more active in developing creative ideas and solutions (Sawyer, 2022).

The results of students' HOTS achievement in this study are also supported by constructivist learning theory. According to Piaget's constructivist theory, students actively construct knowledge through assimilation and accommodation (DeVries, 2000). In this study, the activities in the Let's Analyze!, Let's Evaluate!, and Let's Create! features help students actively process information, connect concepts, and build new knowledge based on learning experiences gained while using the e-worksheet. This aligns with Piaget's view that high school students in grade XI have generally reached the formal operational stage, a stage of cognitive development in which students can think abstractly, logically, hypothetically, and systematically (Miller, 2011; Wilks et al., 2010). Furthermore, HOTS achievement results can also be strengthened by Lev Vygotsky's social constructivism theory, which emphasizes the importance of scaffolding in the learning process. According to Vygotsky, students can develop higher-level thinking competencies if they receive appropriate guidance or support through a focused learning environment and activities (Raslan, 2024). In the developed e-worksheet, scaffolding is provided through activity instructions, prompt questions, contextual case studies, learning multimedia, and systematic activity stages ranging from understanding to application and reflection. Features such as "Let's Get To Know!" help students build initial understanding, while "Let's Analyze!" and "Let's Evaluate!" provide thought stimulation that helps students gradually achieve HOTS skills.

Overall, the HOTS achievement results demonstrate that the Circulation System e-worksheet, based on the Deep Learning approach, is effective for training students' HOTS skills, particularly in analysis (C4), evaluation (C5), and creation (C6). This effectiveness is supported by the e-worksheet design, which integrates the principles of meaningful, enjoyable, and mindful learning through active, contextual, and reflective learning activities. However,

based on validator feedback, the e-worksheet still needs improvements in the reflective learning experience to better facilitate students' self-reflection and self-regulation skills in accordance with the principles of mindful learning.

CONCLUSION

The Circulation System e-worksheet based on the Deep Learning approach to train HOTS of grade XI high school students is declared suitable for use in learning based on the validity of the e-worksheet in the aspects of presentation, content, and language with a very valid category; the practicality of the e-worksheet in the aspect of the implementation of learning activities and positive responses of students in using the e-worksheet with very practical criteria; and the effectiveness of the e-worksheet based on the achievement of HOTS in ≥71% of the total number of students with good to very good criteria scores on the analysis, evaluation, and creation indicators with very effective criteria. The results of this study provide an alternative use of the e-worksheet based on the Deep Learning Approach as a digital teaching material to support the strengthening of HOTS and 21st-century competencies of students. Further research is recommended to optimize reflection activities according to the principles of mindful learning and identify students' initial HOTS conditions so the e-worksheet's effectiveness can be evaluated more objectively.

REFERENCES

Akbar, S. (2013). *Instrumen Perangkat Pembelajaran*. PT Remaja Rosdakarya. https://opac.perpusnas.go.id/DetailOpac.aspx?id=860002

Al Aliyawinata, T. T., Utari, E., & Mahrawi, M. (2021). The Effect of Discovery Learning on Students' Higher-Order Thinking Skills. *International Journal of Biology Education Towards Sustainable Development*, *1*(1), 1–9. https://doi.org/10.53889/ijbetsd.v1i1.47

Alkhatib, O. J. (2019). A Framework for Implementing Higher-Order Thinking Skills (Problem-Solving, Critical Thinking, Creative Thinking, and Decision-Making) in Engineering & Humanities. *2019 Advances in Science and Engineering Technology International Conferences (ASET)*, 1–8. https://doi.org/10.1109/ICASET.2019.8714232

Asmaryadi, A. I., Darniyanti, Y., & Nur, N. (2022). Pengembangan bahan ajar e-LKPD berbasis mikir dengan mengunakan live worksheets pada muatan IPA di sekolah dasar. *Jurnal basicedu*, *6*(4), 7377-7385. https://doi.org/10.31004/basicedu.v6i4.3521

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning : an introduction to school learning*. Grune & Stratton. https://www.scirp.org/journal/paperinformation?paperid=59706

Bordunos, A. K., Miletich, M. P., & Volkova, N. V. (2024). Mindful Learning: Principles and Prospect of Use in Higher Education. *Psychological Science and Education*, *29*(4), 16–30. https://doi.org/10.17759/pse.2024290402

Botha, A., du Toit-Brits, C., & Blignaut, J. H. (2025). Charting New Pathways: Unleashing the Potential of Self-Directed Learning and the Transformative Role of Teachers in Education. *Education Sciences*, *15*(5). https://doi.org/10.3390/educsci15050524

Cheng, A. (2021). The place of language in the theoretical tenets, textbooks, and classroom practices in the ESP genre-based approach to teaching writing. *English for Specific Purposes*, *64*, 26–36. https://doi.org/10.1016/j.esp.2021.07.001

Chisunum, J. I., & Nwadiokwu, C. N. (2024). Enhancing Student Engagement through Practical Production and Utilization of Instructional Materials in an Educational Technology Class: A Multifaceted Approach. *NIU Journal of Educational Research*, *10*(2), 81–81. https://doi.org/10.58709/niujed.v10i2.2002

DeVries, R. (2000). Vygotsky, Piaget, and Education: a reciprocal assimilation of theories and educational practices. *New Ideas in Psychology*, *18*(2–3), 187–213. https://doi.org/10.1016/S0732-118X(00)00008-8

Facione, P. A. (2015). *Permission to Reprint for Non-Commercial Uses Critical Thinking: What It Is and Why It Counts*. Measured Reasons LLC.

Fausan, M. M., Susilo, H., Gofur, A., Sueb, & Yusop, F. D. (2021). *Assessing students' prior knowledge on critical thinking skills in the biology classroom: Has it already been good?* 030016. https://doi.org/10.1063/5.0043167

Feriyanto, F., & Anjariyah, D. (2024). Deep Learning Approach Through Meaningful, Mindful, and Joyful Learning: A Library Research. *Electronic Journal of Education, Social Economics and Technology*, *5*(2), 208–212. https://doi.org/10.33122/ejeset.v5i2.321

Firmansah, G., Raharjo, & Abdillah, F. (2024). Pengaruh Penggunaan Lembar Kerja Peserta Didik Interaktif Berbasis Joyful Learning terhadap Keterampilan Analisis Siswa. *Nusa: Journal of Science Studies*, *1*(1), 20–29.

Fujita, H., & Cunnings, I. (2020). Reanalysis and lingering misinterpretation of linguistic dependencies in native and non-native sentence comprehension. *Journal of Memory and Language*, *115*, 104154. https://doi.org/10.1016/j.jml.2020.104154

Gafur, I. A., Yustina, Suryawati, E., & Hadriana. (2024). Exploring Challenges in Understanding Abstract Biological Concepts: A Visual Literacy Perspective. *Proceedings of the 2nd Annual International Conference on Mathematics, Science and Technology Education*, 234–245. https://doi.org/10.2991/978-2-38476-216-3_25

Gufron, I. A., & Suryahadikusumah, A. R. (2025). Kajian Aksiologi Pembelajaran Berbasis Deep Learning Pada Pendidikan Dasar. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *9*(4), 556–567.

Hackemann, T., Heine, L., & Höttecke, D. (2022). Challenging to Read, Easy to Comprehend? Effects of Linguistic Demands on Secondary Students' Text Comprehension in Physics. *International Journal of Science and Mathematics Education*, *20*, 43–68. https://doi.org/10.1007/s10763-022-10306-1

Istiqomah, E. (2021). Analisis Lembar Kerja Peserta Didik (LKPD) sebagai Bahan Ajar Biologi. *ALVEOLI: Jurnal Pendidikan Biologi*, *2*(1), 1–15. https://doi.org/10.35719/alveoli.v2i1.17

Kementerian Pendidikan Dasar dan Menengah. (2025). *Naskah Akademik Pembelajaran Mendalam: Menuju Pendidikan Bermutu untuk Semua*. Pusat Kurikulum dan Pembelajaran, Badan Standar, Kurikulum, dan Asesmen Pendidikan, Kementerian Pendidikan Dasar dan Menengah Republik Indonesia.

Lestari, I., & Rakhmawati, A. (2024). Pengembangan lkpd berbasis project based learning untuk meningkatkan keterampilan kolaborasi siswa materi bioteknologi. *Jurnal Edukasi Biologi*, 10(2), 177–190. http://dx.doi.org/10.21831/edubio.v10i2.19644

Miller, S. M. (2011). *Transmediating with Multimodal Literacies: Adolescents' Literature Learning Through DV Composing*. 60th Yearbook of the Literacy Research Association. Google Schoolar

Murtonen, M., & Balloo, K. (2019). *Redefining Scientific Thinking for Higher Education* (M. Murtonen & K. Balloo, Eds.). Springer International Publishing. https://doi.org/10.1007/978-3-030-24215-2

OECD. (2023). *PISA 2022 Results (Volume I and II) - Country Notes: Indonesia*. OECD Publishing. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Pertiwi, P., Handoko, H., & Toheri, T. (2020). Pengaruh penerapan meaningful learning berbantuan LKPD bertema terhadap pemahaman konsep matematika dan kemampuan

metakognitif peserta didik. *Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah Di Bidang Pendidikan Matematika*, *6*(2), 127–137. https://doi.org/10.29407/jmen.v6i2.14464

Rahayu, S., & Alsulami, N. M. (2024). *Assessing higher order thinking skills of the 21st century learners using socio-scientific issues as a context*. 070009. https://doi.org/10.1063/5.0214793

Rahma, Q. A., & Kusumawardani, I. N. (2022). Developing Multimodal Mindful Material for Secondary School in Indonesia Post Covid-19 Pandemic. *IDEAS: Journal on English Language Teaching and Learning, Linguistics and Literature*, *10*(2), 1220–1234. https://doi.org/10.24256/ideas.v10i2.3227

Raslan, G. (2024). The Impact of the Zone of Proximal Development Concept (Scaffolding) on the Students Problem Solving Skills and Learning Outcomes. *BUiD Doctoral Research Conference 2023: Multidisciplinary Studies*, *473 LNCE*, 59–66. https://doi.org/10.1007/978-3-031-56121-4_6

Rismana, N., & Hernawati, D. S. (2025). Pengembangan Kurikulum di Indonesia Dalam Menghadapi Tuntutan Abad Ke-21. *Al I'tibar: Jurnal Pendidikan Islam*, *12*(1), 1–8. https://doi.org/https://doi.org/10.30599/sxrd6x96

Ru, C. (2024). Research on the design and application of smart classroom teaching models for promoting deep learning. *MATEC Web of Conferences*, *395*, 01025. https://doi.org/10.1051/matecconf/202439501025

Safitri, R., Syafril, Zuwirna, & Supendra, D. (2024). Pengembangan Lembar Kerja Peserta Didik Elektronik (LKPD-E) pada Mata Pelajaran Informatika Kelas VII SMP. *Jurnal Pendidikan Tambusai*, *8*(1), 11188–11192. https://jptam.org/index.php/jptam/article/view/14058

Sawyer, R. K. (2022). *The Cambridge Handbook of the Learning Sciences* (R. K. Sawyer, Ed.). Cambridge University Press. https://doi.org/10.1017/9781108888295

Shafira, F., Ristiono, R., Alberida, H., & Yogica, R. (2022). The Needs of High Order Thinking Skills-Oriented Student Worksheets on The Human Circulation System Materials For Grade XI Students. *Thinking Skills and Creativity Journal*, *5*(1), 17–21. https://doi.org/10.23887/tscj.v5i1.38500

Silalahi, S. A., Zainal, A., & Sagala, G. H. (2022). *The Importance of Deep Learning on Constructivism Approach*. https://doi.org/10.2991/aebmr.k.220104.036

Singh, D., & Morkel, J. (2024). Neuroscience-Informed Design of Learning Materials: Examining the Impact of Emotion, Interest, and Attention on Learning. *Proceedings of the International Conference on Education Research. Academic Conferences and Publishing Limited*. https://doi.org/10.34190/icer.1.1.3149

Suroya, S. H., Torrens, G. E., & Downs, S. T. (2024). Font Matters: Investigating the Typographical Components of Legibility. *International Journal of Research and Innovation in Social Science*, *VIII*(IX), 3368–3379. https://doi.org/10.47772/IJRISS.2024.8090283

Teplá, M., & Distler, P. (2025). The impact of long-term inquiry-based science education on students' motivation and knowledge acquisition: the role of gender, subject, and level of inquiry. *Humanities and Social Sciences Communications*, *12*(1), 1–12. https://doi.org/10.1057/s41599-025-04437-3

The Partnership for 21st Century Learning. (2015). *Framework for 21st Century Learning*. The Partnership for 21st Century Learning. https://eric.ed.gov/?id=ED519462

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook*. University of Minnesota. https://eric.ed.gov/?id=ED090725

Upara, S., & Chusanachoti, R. (2023). From Real World to Classroom: Navigating English Language Learning through Autonomy-Supportive Instruction and Out-of-Class Resources in Thai EFL Context. *LEARN Journal: Language Education and Acquisition Research Network*, *16*(2), 572–587. https://so04.tci-thaijo.org/index.php/LEARN/index

Vincent, D. J. (2015). *Deepening conceptual understanding in the high school AP biology classroom using engagement tools and techniques*. Michigan State University. https://d.lib.msu.edu/etd/2919

Waruwu, M. (2024). Metode Penelitian dan Pengembangan (R&D): Konsep, Jenis, Tahapan dan Kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, *9*(2), 1220–1230. https://doi.org/10.29303/jipp.v9i2.2141

Wilks, T., Gerber, R. J., & Erdie-Lalena, C. (2010). Developmental Milestones: Cognitive Development. *Pediatrics in Review*, *31*(9), 364–367. https://doi.org/10.1542/pir.31-9-364

Yeşilyurt, S., & Gül, Ş. (2012). Secondary School Students' Misconceptions About the "Transportation and Circulatory Systems" Unit. *Journal of Theoretical Educational Science*, *5*(1), 17–48. http://www.keg.aku.edu.tr

Zhou, T., & Colomer, J. (2024). Cooperative Learning Promoting Cultural Diversity and Individual Accountability: A Systematic Review. *Education Sciences*, *14*(6), 567. https://doi.org/10.3390/educsci14060567