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Development of Differentiated E-LKPD Integrated with HOTS and Multiple Intelligences to Enhance Students' Systems Thinking Skills

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Abstract: This study aims to develop differentiated electronic student worksheets (e-LKPD) integrated with Higher-Order Thinking Skills (HOTS) and multiple intelligences that are valid, practical, and effective in enhancing students' systems thinking skills. The research follows the Borg and Gall R&D model. The study population comprised eighth-grade students from SMPN 1 Mesuji in the 2024/2025 academic year. A purposive sampling technique was employed to assign class VIIIA as the experimental group and class VIIIB as the control group. Data collection instruments included need analysis questionnaires, expert validation forms, student and teacher response questionnaires, pretest and posttest items, reflection sheets, and learning implementation observation sheets. Data analysis was conducted using independent sample t-tests on n-Gain scores. The findings revealed that: (1) the e-LKPD was rated as highly valid (95%) by expert reviewers; (2) it was considered highly practical by students (95%) and teachers (100%); (3) it was effective in improving systems thinking skills with a high n-Gain score (0.75) and a large effect size (0.95); and (4) it achieved a very high implementation level (87.19%). These results indicate that the developed e-LKPD is suitable for use in science learning, particularly on the topic of the digestive system, to enhance students' systems thinking skills.

Keywords: Differentiated instruction; E-LKPD; Higher-order thinking skills; Multiple intelligences; Systems thinking skills

Introduction

Systems thinking skills represent a form of higher-order thinking that is essential to develop within the educational process (Zoller et al., 2011). These skills enable students to comprehend problems holistically by identifying relationships among components within a system, thereby facilitating the formulation of effective solutions (Casnan et al., 2022; Clark et al., 2017). Moreover, systems thinking supports the ability to connect seemingly unrelated concepts and formulate problem-solving strategies in learning contexts (Schuler et al., 2018). Consequently, mastering systems thinking enhances the quality of learning and equips students to tackle complex challenges in everyday life. However, science education in Indonesia continues to emphasize cognitive outcomes and the transmission of isolated facts (Nurdin, 2019), which often results in students struggling to interrelate different scientific concepts.

Previous studies indicate that Indonesian students' systems thinking skills remain at relatively low levels (Faza et al., 2023; Nuraeni et al., 2020; Weinert, 2001). This issue stems from the suboptimal use of instructional methods that cultivate systems thinking, limited availability of relevant learning resources, and teachers' insufficient capacity to design instruction that fosters

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such skills. Additionally, teaching materials like e-LKPDs commonly used in science classrooms are not specifically developed to support differentiated instruction that considers students' varying needs, interests, and learning profiles (Faza et al., 2023; Raved et al., 2014; Roehl et al., 2013).

The implementation of the Independent Curriculum, which embraces differentiated learning, offers opportunities to enhance systems thinking skills. Differentiated instruction allows educators to tailor content, processes, and learning products to meet individual student needs (Kristiani et al., 2021). When combined with Higher-Order Thinking Skills (HOTS) and the theory of multiple intelligences (Lazear, 2004), students can engage in deeper conceptual understanding and express their learning outcomes according to their cognitive strengths and preferences (Destari et al., 2022; Fitriyah et al., 2023). For example, the topic of the digestive system is particularly suitable for systems thinking development, as it encompasses complex and abstract concepts including organ structures, digestive mechanisms, and various disorders (Maulida et al., 2022; Simorangkir et al., 2020; Wilujeng, 2018).

Survey findings reveal that most science teachers in Indonesia have yet to adopt teaching resources designed to enhance systems thinking. Many also face challenges in nurturing students' higher-order thinking skills. Therefore, the development of interactive and accessible teaching materials that accommodate diverse student needs is critical. A differentiated e-LKPD that integrates HOTS and multiple intelligences offers a promising solution to support 21st-century learning goals. Such materials aim not only to deepen conceptual understanding and promote systems thinking but also to empower students to apply scientific knowledge to real-world situations. Thus, research and development in this area serve as a strategic effort to create learning experiences that advance academic achievement while simultaneously cultivating essential thinking competencies.

Method

This study employed a Research and Development (R&D) design based on the model proposed by Borg and Gall (2003), consisting of ten stages: (1) research and information gathering (preliminary study), (2) planning, (3) development of a preliminary product draft, (4) preliminary field testing, (5) revision of the main product, (6) main field testing, (7) revision of the operational product, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. The product developed in this study is a differentiated electronic student worksheet (e-LKPD) integrated with Higher-Order Thinking Skills (HOTS) and multiple intelligences to enhance students' systems thinking skills. The development procedure is illustrated in Figure 1.

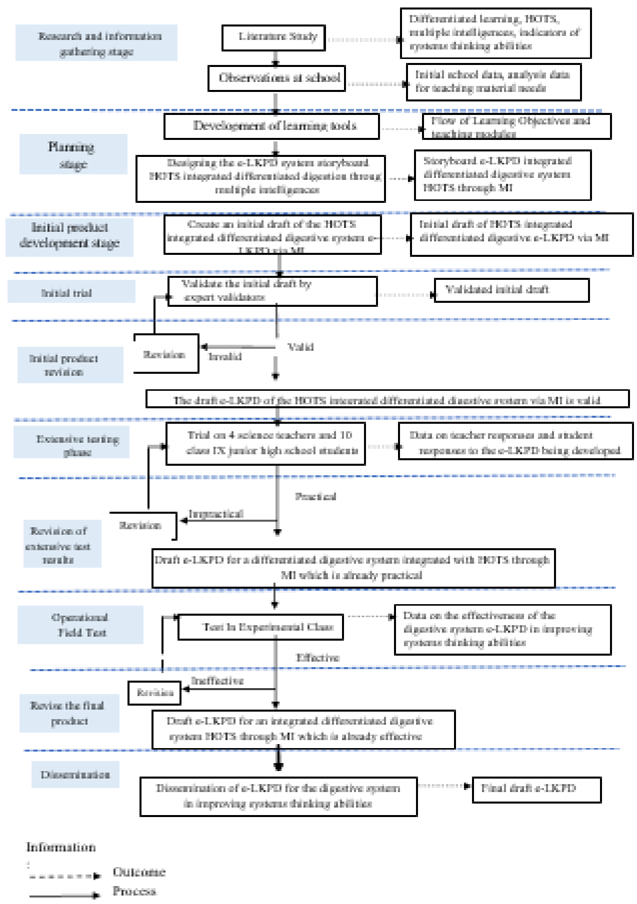

Figure 1. Development procedure (Sunyono, 2014; Wardani, 2023)

The research instruments included: (1) a preliminary study questionnaire for teachers and students, (2) expert validation sheets covering content suitability, construct validity, and readability, and (3) teacher and student response questionnaires. The validation criteria assessed by teachers and students covered aspects such as ease of use, attractiveness, usefulness, and readability. Additional instruments included pretest and posttest questions designed to assess students' systems thinking skills.

The sampling technique used was cluster random sampling, with class VIII-A selected as the experimental group and class VIII-B as the control group. Data analysis involved descriptive statistics of expert validation and user responses using interpretation criteria by Arikunto (2019), independent sample t-tests to compare the effectiveness of the intervention, and effect size analysis to measure the magnitude of the e-LKPD's impact on students' systems thinking skills.

Table 1. Validation Percentage Criteria

Percentage (%)	Validity level	Description
76 – 100	Valid	Appropriate/No revision needed
51 – 75	Fairly valid	Adequate/Partial revision
26 – 50	Quite valid	Inadequate/Partial revision
< 26	Invalid	Not feasible/ Major revision needed

Table 2. Practicality Percentage Criteria

Percentage (%)	Practically level	Description
76 – 100	Practical	Applicable/No revision needed
51 – 75	Fairly practical	Adequate/Partial revision
26 – 50	Less practical	Less applicable/Partial revision
< 26	Impractical	Not applicable/ Major revision needed

Result and Discussion

The development of a differentiated e-LKPD integrated with HOTS and multiple intelligences followed the ten stages of the Borg et al. (1983) model The main stages of the product development are outlined as follows:

Research Information Collection

This stage consisted of a literature review and curriculum analysis. The literature review included theories related to e-LKPDs, differentiated instruction, HOTS, and multiple intelligences as formulated by Lazear (2006), which categorizes learning into three levels: acquiring and understanding basic knowledge, processing and analyzing information, and engaging in higher-order thinking and reasoning. The systems thinking skills framework used in this study comprised indicators such as interconnection, synthesis, emergence, feedback loops, causality, and system mapping. The instructional model employed was Problem-Based Learning (PBL), adapted from Fogarty (1997), which involves five phases: (1) orienting students to the problem, (2) organizing students for learning, (3) guiding individual and group investigations, (4) developing and presenting results, and (5) analyzing and evaluating the problem-solving process.

Curriculum analysis focused on determining the Learning Outcomes (LO) aligned with the Independent Curriculum issued by the Indonesian Ministry of Education and Culture. The targeted LO for this study was: "By the end of phase D, students can understand the functions and possible disorders of organ systems (including the digestive system)."

Field studies included teacher interviews, a needs analysis questionnaire for 22 teachers from 15 junior high schools, and 100 students from 12 junior high schools in Lampung Province. These instruments helped assess current practices and the necessity for developing e-LKPDs that enhance systems thinking skills.

Table 3. Summary of Teachers' Responses Regarding e-LKPD Usage

Statements	Percentage (%)
Do you use LKPDs in teaching the digestive system?	68
Do you consider e-LKPDs important in the digital era?	86
Have you ever developed or modified e-LKPDs for the digestive system?	32
Does your current LKPD support basic knowledge acquisition?	37
Does your current LKPD support information analysis?	32
Does your current LKPD support higher-order thinking and reasoning?	38
Does your current LKPD accommodate students' multiple intelligence?	23
Is there a need to develop an e-LKPD that enhances systems thinking?	86

Table 4. Summary of Students' Responses Regarding e-LKPD Usage

Statements	Percentage (%)
Are you interested in digital learning materials?	89
Does your current LKPD address your learning needs?	22
Does your LKPD help develop higher-order thinking?	12
Does your LKPD help analyze interconnections and patterns?	31
Are you interested in using interactive e-LKPDs that promote systems thinking?	88

These findings confirmed the need for an e-LKPD that integrates HOTS and multiple intelligences within a differentiated learning approach to foster students' systems thinking skills. Special attention was given to intrapersonal and interpersonal intelligences to promote reflective, collaborative, and communicative learning (Ab-Hajis et al., 2024; Kasrah et al., 2024). The integration of HOTS also encourages students to evaluate and synthesize information, facilitating the identification of systemic patterns in the digestive system (Ibrahim et al., 2024)(. Furthermore, the PBL model offers authentic learning experiences where students apply systems thinking collaboratively (Tan, 2021).

Planning and Product Drafting

This stage included identifying learning objectives, analyzing instructional needs, designing a module, and developing the e-LKPD storyboard. The final product consisted of three main parts: First, introduction. It consists of cover page, foreword, table of contents, user guide, learning outcomes, competency indicators, and learning objectives. Second, main content. It consists of activities based on PBL, HOTS, and multiple intelligences. Three differentiated e-LKPDs were developed based on digestive disorders: obesity (e-LKPD 1), diabetes mellitus (e-LKPD 2), and constipation (e-LKPD 3). Third, closing section, consists of bibliography and developer's profile.

Preliminary Field Testing

Validation was conducted by two expert lecturers, assessing content, construct, and readability. The results showed high validity:

Table 5. Expert Validation Results

Aspect	Score (%)
Content validity	92
Construct validity	97
Readability	95
Average	96

This suggests the developed e-LKPD is feasible for classroom use and aligns well with educational standards (Sarita et al., 2020).

Main Field Testing

The e-LKPD was trialed with a small group of 10 ninth-grade students (3 high, 4 medium, 3 low ability) and 4 science teachers.

Table 6. Teacher Responses (n=4)

Aspect	Score (%)
Ease of Use, Attractiveness, Usefulness, and Readibility	100

Table 7. Student Responses (n=10)

Aspect	Score (%)
Ease of Use, Attractiveness, Usefulness, and Readibility	95

Both teacher and student responses indicated a "very high" level of practicality, suggesting the e-LKPD was engaging, understandable, and beneficial for learning.

Operational Field Testing

The operational field test aimed to assess the effectiveness of the developed e-LKPD in enhancing students' systems thinking skills. The learning process was carried out in both the experimental and control classes over three sessions. Students in both groups were administered a pretest before the intervention and a posttest afterward.

Table 8. Indicators of Systems Thinking Skills (Zvi - Assaraf et al., 2010)

Indicators of systems thinking ability
The ability to identify system components and processes.
The ability to recognize relationships among system components.
The ability to understand dynamic interactions within a system.
The ability to organize system elements within a framework of relationships
The ability to comprehend the cyclical nature of systems

Table 9. Average Pretest-Posttest Scores in Experimental and Control Classes

Class	Pretest	Posttest	Score Increase
Control	17.60	56.40	29.50
Experimental	15.31	79.06	63.75

Table 10. Average n-Gain Values of Systems Thinking Skills

Class	n-Gain	Category
Control	0.47	Moderate
Experimental	0.75	High

The data in Table 9 and Table 10 show that the experimental class, which used the differentiated e-LKPD integrated with HOTS and multiple intelligences, demonstrated a significantly higher increase in systems thinking skills compared to the control group using conventional worksheets. These findings align with Hake's (1999) n-Gain criteria and indicate a substantial learning improvement.

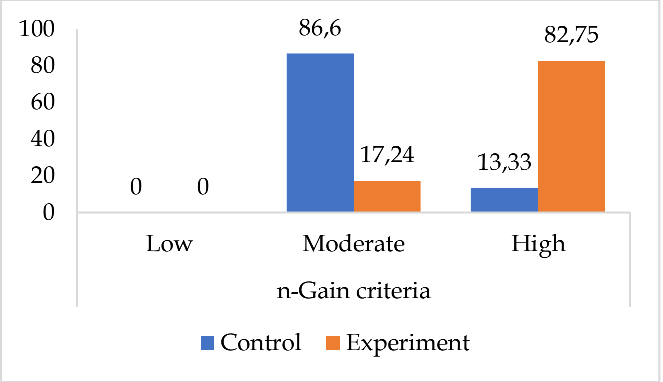

Figure 2. Distribution of students' n-gain score criteria in experimental and control classes

The distribution of students according to n-Gain score criteria shows that the experimental group had more students in the "high" category, while the control group had more in the "moderate" range. Both groups had similar proportions of students in the "low" category.

To test the statistical significance of the learning gains, an independent samples t-test was performed, after confirming the assumptions of normality and homogeneity.

The results indicate that the data were normally distributed and homogeneous. The t-test showed a significant difference ($p < 0.05$) between the experimental and control groups. The effect size of 0.95 suggests a large impact of the intervention on students' systems thinking skills.

Table 11. Statistical Test Results of Students' System Thinking Ability

Class	Normality (Sig.)	Homogeneity (Sig.)	T-test (Sig. 2-tailed)	Effect Size	Category
Control	0.095	0.194	0.00	0.95	Large
Experiment	0.419				

These results are consistent with previous studies showing that differentiated PBL models positively influence thinking skills (Ayuning, 2023; Kumalasari et al., 2024; Oktaviana, 2023; Rahayu et al., 2022). In addition, HOTS-based learning strategies—focusing on analyzing, evaluating, and creating—help students develop the ability to think critically, logically, and systematically (Sari et al., 2022).

Importantly, no significant differences were found among students with different initial cognitive abilities (high, medium, low), indicating that the e-LKPD was equally effective across all student groups. The differentiated approach, therefore, helped minimize learning disparities.

Furthermore, the detailed analysis of each indicator of systems thinking revealed that students in the experimental group consistently achieved higher n-Gain scores across all dimensions. This improvement was also reflected in their ability to construct concept maps that linked the causes, processes, and solutions related to digestive system disorders such as obesity and constipation—demonstrating a functional understanding of systemic interactions among diet, organ function, lifestyle, and prevention strategies.

In today's educational landscape, systems thinking skills are crucial for connecting concepts and addressing real-world challenges. These skills enable students to understand hierarchical structures, interrelationships, and dynamic feedback within systems, as well as to integrate knowledge across disciplines (Gilbert et al., 2019).

Conclusion

Based on the results of this research and the validation process conducted by experts, the developed differentiated e-LKPD integrated with Higher-Order Thinking Skills (HOTS) and multiple intelligences was found to be highly valid in terms of content, construct, and readability. The practicality test results showed a very high level of feasibility, as evaluated by both teachers and students. These findings indicate that the e-LKPD is suitable for use as a teaching resource in science education. Furthermore, the effectiveness of the developed e-LKPD in improving students' systems thinking skills was demonstrated through field trials. The average n-Gain in the experimental class was higher than that in the control class, and the calculated effect size was 0.95, categorized as large. This shows that the developed e-LKPD has a significant positive impact on students' ability to understand, analyze, and apply systems thinking, especially within the topic of the human digestive system.

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Author Contributions
The author was responsible for the entire development and preparation of this research article, including concept design, data collection, analysis, and manuscript writing.

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Conflicts of Interest
The author declares no conflict of interest.

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