

Enhancing Systems Thinking Skills with E-Worksheets Representation Model

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Abstract: This study aims to develop multi-representation model e-worksheets to improve students' systems thinking skills on the human locomotor system. This study is a research and development (R & D) that refers to the 10 steps of Gall et al.'s model development. This study involved 100 students and 11 teachers at the information gathering stage, 2 e-worksheets validators at the limited field test stage, the main field test involved 15 students and 2 science teachers, while the operational field trial involved 64 students in grades VII.2 and VII.3 at SMP Negeri 2 Sekampung using a pretest-posttest control group design. The instruments in this study included a questionnaire on teacher and student needs, a questionnaire on e-worksheet validation aspects of content, construction and readability, a questionnaire on student and educator responses to e-worksheets, and pretest-posttest questions on systems thinking skills. The qualitative data analysis technique in this study used descriptive analysis and quantitative data used an independent sample t-test. The results of the validation of e-worksheets by experts stated that the developed e-worksheets were valid with the criteria of "very high" and based on the responses of teachers and students, the practical e-worksheets had the criteria of "very high". The results of the independent sample t-test obtained a sig.2 tailed value of 0.000, meaning that the average value of the systems thinking skills of students in the experimental class was higher than the control class, with an average n-gain in the control class of "0.32" while the experimental class was "0.71". This is supported by the results of the effect size test of "0.871" which states that the developed e-worksheets have a very large influence in improving students' systems thinking skills.

Keywords: E-worksheets; System thinking skills; Representation model

Introduction

Systems thinking skills are essential for students to understand the complexity of human relationships as they navigate the latest developments toward sustainable development worldwide. When students possess these skills, it becomes easier to connect one topic to another (Schuler et al., 2018). This skill makes connections between previously seemingly unrelated problems become interconnected (Clark et al., 2017). Systems thinking can lead students to transition in viewing problems from not just components to seeing the relationships between components, then seeing the interconnected relationships, and finally seeing the interdependencies between components. This skill enables humans to gradually understand problems

better, and a better understanding can open up opportunities for better solutions (Bungsu et al., 2021).

Schuler et al. (2018) stated that systems thinking can contribute to the development of student understanding. Systems thinking skills help students make decisions to avoid mistakes because systems thinking helps connect and make various decisions while considering the impact of those decisions (Clark et al., 2017). Rohmadi (2018) stated that the process of systems thinking will produce a thought result that will later affect an action or behavior.

Based on data obtained from the Programme for International Student Assessment (PISA), systems thinking skills are one of the aspects assessed in the assessment conducted by the Organisation for Economic

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Cooperation and Development (OECD). The average results in 2023 decreased compared to 2018, so the low PISA results can indicate that students' systems thinking skills are also at a low level (OECD, 2023). In line with research conducted by Nuraeni et al. (2020), it states that teachers and students have not connected the material with other concepts, so connections between concepts are difficult to obtain when solving systems thinking skills problems. Therefore, it can be said that students' systems thinking skills are still in the low category. This occurs due to the still suboptimal activities to train systems thinking skills in the learning process and the lack of research on systems thinking skills in education. Raved et al. (2014) stated that students' low systems thinking skills are influenced by students' tendency to solve problems using only one method without considering or showing other alternative methods. Although systems thinking skills in science learning should be applied by connecting one concept to another, the learning process often focuses on one concept without connecting it to other concepts (Roehl et al., 2013). One reason is that systems thinking skills have not been optimally practiced in learning through models, strategies, and learning approaches that can empower students' systems thinking skills (Pandra et al., 2024).

Moore et al. (2018) stated that the use of multiple representations provides insights that enable students to develop their skills in engaging with abstract representations, which will become part of future practices related to activities in science, mathematics, and engineering. The application of multiple representations improves student understanding (Fauza et al., 2023). Students' thinking skills improve with the application of multiple representations compared to conventional learning (Kusumaningsih et al., 2018).

The multiple representation learning model is appropriate for learning about movement systems. The concept of movement systems encompasses an understanding of how the human body or other living things move and interact with their environment. Understanding the concept of motion systems requires visualization using teaching materials. These teaching materials are essential in the science learning process (Sari et al., 2021).

Teaching materials play a crucial role in learning, serving as a representation of the teacher's explanations in class. The use of multiple representations provides students with the opportunity to learn according to their preferred learning style, resulting in better learning outcomes. Multi-representation-based science teaching materials are a self-learning medium that facilitates independent science learning and provides a rich context for students to correctly understand science concepts. This minimizes conceptual errors and effectively achieves learning objectives (Pratiwi, 2022).

In fact, teachers generally still use traditional teaching methods with pre-existing printed teaching materials. This, of course, does not optimize information delivery and does not stimulate students to utilize technology effectively to acquire knowledge, as is the urgency of 21st-century education (Sari et al., 2021). According to Sugianto et al. (2018), the suboptimal development of teaching materials and the limited availability of science teaching materials prevent students from implementing learning activities in accordance with the characteristics of science and their needs. The importance of developing appropriate and effective teaching materials to meet student needs in the form of student worksheets (LKPD) integrated with technology, namely e-worksheets, can be a solution to increase the effectiveness of learning, especially in science subjects. According to Sya'idah et al. (2020), e-worksheet-assisted learning has an impact on student learning outcomes.

Research that develops e-worksheets Integrated multi-representation model STEM (Asrizal et al., 2023; A. Putri et al., 2022; Sari et al., 2021), in addition the use of multiple representations in teaching materials has become a research trend in the world of education (Ardwiyanti et al., 2021; Abdurrahman et al., 2019;), but e-worksheets Multi-representation model specifically designed to improve systems thinking skills has not been widely carried out by other researchers, especially in the study of motion systems. Systems thinking is a critical aspect that needs to be developed in natural science learning. Based on this, researchers are interested in developing teaching materials in the form of e-worksheets based on representation models to improve students' systems thinking skills.

Method

This research is a research and development (R&D) that refers to the development model of Borg et al. (1998). The research was conducted to produce a product, namely e-worksheets representation model to improve students' systems thinking skills. In this study, the researchers developed e-worksheets according to the Borg et al. (1998) model but only in Steps 1-9, namely research and information collection, planning, initial product development, limited field testing, initial product revision, main field testing, product revision resulting from the main field testing, operational field testing, final product revision. Participants in this study included 100 students and 11 science teachers in East Lampung Regency at the needs analysis stage for the e-worksheets to be developed, two science experts who validated the e-worksheets representation model developed including aspects of content suitability, construction, and readability. Furthermore, participants

in the e-worksheets practicality test included 2 science teachers and 15 students at SMP Negeri 2 Sekampung. The practicality aspects assessed included ease, attractiveness, usefulness, and readability. The effectiveness test of the representation-based e-worksheets was conducted using a pretest-posttest control group design (Fraenkle et al., 2012). The population in this study were seventh-grade students at

SMPN Negeri 2 Sekampung, with a sample of 64 students selected using a purposive sampling technique. Class VII B was selected as the experimental class, which implemented learning using the representation-based e-worksheets, while class VII A was designated as the control class, which implemented conventional learning. The stages of this research are shown in Figure 1.

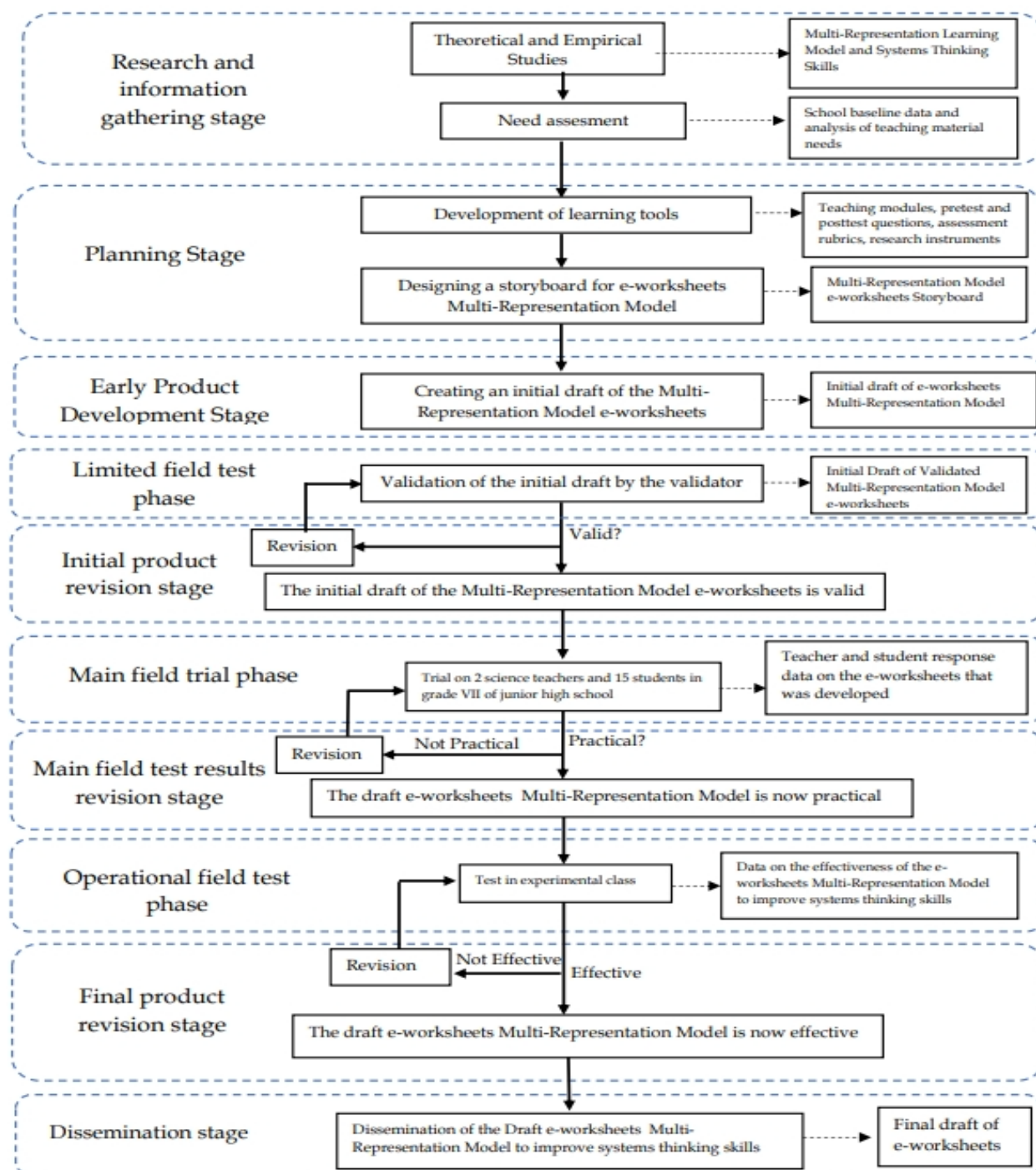


Figure 1. Research procedures

The instruments in this study include pretest-posttest questions on students' systems thinking skills

totaling 15 questions according to the hierarchy of systems thinking skills according to (Assaraf et al., 2010).

Questionnaires on teacher and student needs, e-worksheets validation questionnaires by experts regarding aspects of content suitability, construction, and readability. Questionnaires on the practicality of e-worksheets which include ease, readability, usefulness, and attractiveness assessed by teachers and students. The e-worksheets validation questionnaire by experts,

and practicality by teachers and students were conducted using a Likert scale with a value of 1 meaning strongly disagree, 2 disagree, 3 disagree, 4 agree, 5 strongly agree, after which the average value of expert, teacher, and student answers was calculated. The validity and practicality criteria of e-worksheets are shown in Table 1.

Table 1. E-Worksheets Validation/ Practical Criteria

Percentage	Validity Level	Description
76% – 100%	Valid/ Practical	Worthy/no need for revision
51% – 75%	Fairly Valid/ Practical	Decent enough/partial revision
26% – 50%	quite valid/ Practical	Inadequate/partial revision
< 26%	Invalid/ Impractical	Not feasible/total revision

The data analysis of the effectiveness of e-worksheets was carried out using descriptive statistical analysis while the pretest-posttest data obtained were then calculated for the students' n-Gain value and interpreted according to Hake (2002) in Table 1. Furthermore, the n-Gain value that had been obtained was analyzed using SPSS version 25.0 using the independent sample t-test. Then, the effect size value was calculated based on Cohen (1988).

$$N - gain = \frac{\text{posttest score} - \text{pretest score}}{100 - \text{pretest score}} \quad (1)$$

Table 2. N-Gain Criteria

N-Gain	Criteria
> 0.7	High
0.3 < N-Gain ≤ 0.7	Medium
N-Gain ≤ 0.3	Low

Result and Discussion

The first stage in this research is research and information collection, namely collecting data and information needed in developing e-worksheets Multi Representation Model to improve system thinking skills which include theoretical studies and empirical studies. The results of the theoretical study include the syntax of the multi representation model referred to in this research using Lengkana (2018), consisting of six phases (1) initial knowledge phase of visual representation, (2) phenomenon presentation phase, (3) key concept identification phase, (4) exploration phase, (5) construction phase, (6) presentation and interpretation phase. In addition, the hierarchy of system thinking skills used was adopted from Ben-Zvi-Assaraf et al (2010) consisting of 8 hierarchies, namely identifying system components and processes in the system, identifying relationships between system components, identifying dynamic relationships within the system, organizing system components and processes in a relationship framework, organizing system components

and processes in a relationship framework, understanding the nature of the system cycle, making generalizations, understanding the hidden dimensions of the system, and thinking temporarily: retrospection and prediction. The content analysis of the material used was focused on the human movement system in seventh-grade junior high school students. The components of the movement system are bones (structure, function, types, forms, and diseases), muscles (types, functions, muscle function), joints (types, movement, function), relationships between components (e.g., the role of joints and muscles in bone movement), and disorders or disorders of the movement system (rickets, scoliosis, osteoporosis).

The results of an empirical study conducted on 100 students and 11 science teachers in nine junior high schools across East Lampung revealed the current Merdeka curriculum. The learning approach used by teachers was a scientific approach (72%), contextual approach (18%), and other approaches (10%). The learning models used by teachers in the learning process were discovery learning, inquiry (63%), problem-based learning (9%), project-based learning (9%), and inquiry (18%). Most teachers used teaching materials from the Ministry of Education and Culture (90%), and internet materials (1%), not in electronic form. Furthermore, 100% of teachers stated that electronic-based teaching materials are important in the digital 4.0 era. Eighty-seven percent of the teaching materials teachers use present both material and images, while 18% present both material and images and videos. The teaching materials teachers use are not yet equipped with components to improve systems thinking skills. Teachers have never created or modified electronic worksheets for the movement system topic.

An empirical study of students found that the majority of students enjoyed science material, and they also stated that science material, particularly the motor system, was complex. The teaching strategies used by teachers so far have not helped students understand the

material. The teaching strategies used in schools include lectures and assignments, resulting in students experiencing difficulties in understanding the motor system material. The teaching materials used by students at school to understand the motor system material include printed textbooks from the Ministry of Education and Culture and student worksheets (LKPD). The presentation of the teaching materials is primarily visual. The LKPD used by students is paper-based and unengaging, containing only images and text.

Based on the empirical study, it was concluded that the components contained in the science teaching materials, which teachers present only in the form of images, make it difficult for students to understand the material, even though they express a liking for science. Students need teaching materials that can bridge the connections between concepts visually and conceptually. The media used in the teaching materials lacks variety and does not develop students' systems thinking skills.

The second stage in this research is planning, the researcher compiled the teaching module, e-worksheets storyboard, expert validation questionnaire, teacher and student response questionnaire to e-worksheets, pretest and posttest questions, assessment rubric, and e-worksheets creation. The e-worksheets design has a visual representation in the form of images and videos of the movement system, muscles, bones, joints), has a verbal representation in the form of narrative explanations, has a symbolic representation in the form of mind mapping, has a concrete representation in the form of daily activities involving the movement system. The developed e-worksheets contains exploratory activities, namely analyzing images, matching functions and disorders. Contains systems thinking exercises by filling in mind maps of the relationship between the structure and function of organs and explaining the consequences if one component is disturbed. Presenting contextual problems, students are given questions to analyze. Emphasizes multiple representations to strengthen students' understanding.

The third stage is the development of the initial product. The creation of e-worksheets is based on the results of a theoretical study using Lengkana's syntax (2018) which at each stage contains a hierarchy of systems thinking skills. The developed e-worksheets was created using the Canva application and converted into electronic form using LiveWorksheets. In the initial visual representation knowledge phase, students are given introductory learning, providing initial knowledge about the function of representation modes in the movement system contained in the e-worksheets. Students observe the information contained in the barcode, which is useful as a trigger to encourage students to ask questions related to the topic of the

material to be discussed. There is also a QR code containing a news video. In the phenomenon presentation phase, the educator begins learning by displaying the phenomenon in several ways (multi-representation). At meeting 1, the discourse is presented in the form of a movement system video that can stimulate students' systems thinking skills. At meeting 2, the discourse presentation contains the concept of the movement system, namely the concept of disorders that attack bones, and meeting 3, the discourse presentation contains the concept of the movement system, namely the concept of disorders that attack muscles in text form. key concept identification phase. Educators guide students to analyze and identify key concepts (essential core concepts) in each topic or subtopic of the material and to connect cross-domain concepts within the phenomenon.

In the exploration phase, activities in the e-worksheets involve students working in groups to explore available learning resources (Ministry of Education and Culture books and the internet). The information sought refers to the key concepts discovered in the identification phase. Videos and articles in QR codes serve as useful sources for investigations, covering movement system disorders, including their causes, as outlined by health experts. Students are directed to find comprehensive information regarding the causes of disorders or abnormalities to answer the information sought, referring to key concepts. The construction phase involves problem-solving activities using/constructing pre-prepared representations, including mind maps and descriptive questions, as shown in the figure. Each session has different questions based on the concepts presented. Construction activities represent an internal representation of the exploration concept. In the presentation and interpretation phase, students communicate the concepts they have learned in the form of representations through group presentations, while educators conduct reviews and assessments to strengthen the students' concepts.

In the limited field testing phase, a validation test was conducted to determine the validity of the Multi-Representation Model e-worksheets to improve the developed systems thinking skills. The results of the e-worksheets validation conducted by two expert lecturers who assessed the aspects of content suitability, construction suitability, and readability are shown in Table 3. The expert validation results indicate that the representative model e-worksheets for improving systems thinking skills is valid with a "very high" criterion. Astalini et al. (2019) state that a product is considered valid if the expert validation results reach the very high category, namely above 85%. This high percentage is due to the e-worksheets containing multi-representation aspects, each syntax containing a

hierarchy of systems thinking skills, activities in the e-worksheets aligning with learning objectives, good quality, compliance with the independent curriculum, and easy access to answer questions.

After product validation, the next stage is revising the initial product. Improvements are made based on suggestions and input from the validator. The suggestions and results of the e-worksheets improvements are shown in Table 12. Next, the main field test stage, the purpose of this stage is to determine the practicality of the e-worksheets that has been developed. The subjects at this stage were 2 science teachers and 15 seventh-grade students at SMPN 2 Sekampung. The results of the e-worksheets practicality test are shown in Tables 4 and 5. The results of the practicality test state that teachers and students agree that the e-worksheets product is a representative model for improving practical systems thinking skills with a "very high" category. The practicality percentage value is greater than 85% with a positive response from students, indicating that the product is practical and ready for use in the classroom (Januarti et al., 2024). The high practicality of e-worksheets is due to its ease of use, suitability to the needs of students and teachers, and support a smooth learning process. This high practicality score indicates that neither teachers nor students experienced significant obstacles in accessing, understanding, and using e-worksheets during learning activities. This finding aligns with research by (Salsabila et al. (2021), which found that e-worksheets can increase accessibility and student engagement in learning due to its flexibility, accessibility, and interactive nature. Furthermore, Wulandari et al. (2021) also found that using e-worksheets based on interactive digital media in science learning can improve time efficiency, facilitate concept understanding, and increase student motivation.

The next stage was revising the product resulting from the main field test. Based on teacher and student responses to the developed e-worksheets, several suggestions were made by students regarding the readability of the e-worksheets, including improvements to the font size in the answer column, which needs to be enlarged to make it easier for e-worksheets users to read.

Table 3. Results of Worksheets Validation by Experts

Validation Aspects	Percentage (%)
Suitability of content	95%
Suitability of construction	92%
Readability	90%

Table 4. Results of Teacher Responses to Worksheets

Aspects	Percentage (%)
Convenience	100%
Attractiveness	100%
Usefulness	91%
Readability	100%

Table 5. Results of Students Responses to Worksheets

Aspects	Percentage (%)
Convenience	100%
Attractiveness	100%
Usefulness	92%
Readability	100%

An operational field trial was conducted to determine the effectiveness of e-worksheets in improving students' systems thinking skills. The subjects at this stage were 64 students, divided into an experimental class of 32 students (grade VII.3) and a control class of 32 students (grade VII.2). The experimental group conducted learning on the movement system using the developed e-worksheets representation model, while the control class conducted learning on the movement system using teaching materials commonly used by educators, namely textbooks published by the Ministry of Education, Culture, Research, and Technology. The pretest and posttest results of students in the control and experimental classes are shown in Table 6. Posttest scores for both the control and experimental classes increased, but the increase in the experimental class was significantly greater than in the control class.

Furthermore, the increase in pretest-posttest scores for students' systems thinking skills can be demonstrated through the n-gain value calculated using the formula proposed by Hake (2002). Based on the calculations that have been carried out, the percentage of the n-Gain value criteria for the systems thinking skills of the control class and the experimental class is obtained as presented in Table 2. The experimental class obtained an average n-Gain in the "high" category while the control class was categorized as "moderate". This is because the experimental class implemented learning using the e-worksheets representative model. Furthermore, Nuraeni et al. (2020) stated that systems thinking will make it easier for students to connect one material with another more easily.

Table 6. Pretest-Posttest Values of Students' System Thinking Skills

Class	Pretest	Posttest	Pretest-posttest increase
Control	12.42	40.00	27.58
Experiment	13.00	74.25	59.25

Table 7. N-Gain Values of Students' System Thinking Skills

Class	Average n-Gain	Criteria
Control	0.32	Medium
Experiment	0.71	High

Table 8. Results of the N-Gain Normality Test of Students' System Thinking Skills

Class	Average n-Gain	Sig. test of Normality Kolmogorov-Smirnov
Control	0.32	0.200
Experiment	0.71	0.194

Table 9. Results of Homogeneity Test of Students' System Thinking Skills

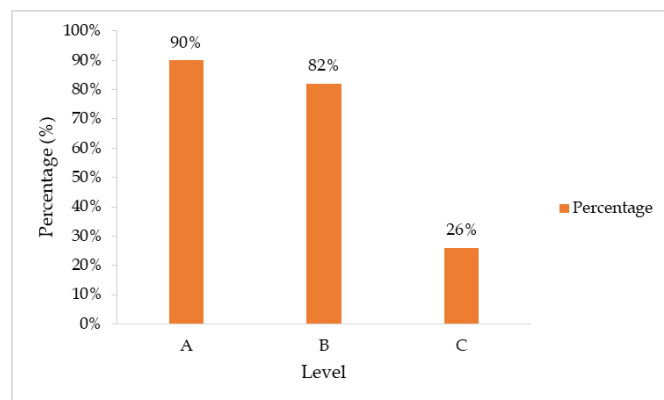
Class	Average n-Gain	Sig.
Control	0.32	0.100
Experiment	0.71	

Table 10. Results of the Independent Sample t-Test of Students' System Thinking Skills

Class	Average n-Gain	Sig. 2 tailed
Control	0.32	
Experiment	0.71	0.000

Table 11. Effect Size

Effect Size Value	Criteria
0.871	Large

**Figure 2.** Students' systems thinking skill level

The results of the analysis of students' systems thinking levels are shown in Figure 2. This indicates that students' systems thinking skills have only been achieved at levels A and B, namely Level A: identifying system components and processes. Level B: identifying relationships between components, dynamic relationships, and understanding cycles in the system. This achievement has not yet reached level C, namely making generalizations, understanding hidden dimensions, and temporal thinking, as described in Keynan's (2014) levels. These results indicate that the majority of students are more capable of identifying and analyzing system components, but still have difficulty

synthesizing complex systems and implementing them comprehensively, especially in retroactive and predictive systems thinking. Research by Putri et al. (2024) and Saputra et al. (2020) shows that junior high school students are still in the development stage of abstract and systemic thinking skills. Students tend to be better able to identify simple components and relationships than to think holistically and complexly as required at Level C. (Nuraeni et al., 2020).

Based on the results of the n-Gain normality test for students presented in Table 8, the systems thinking skills of both the control and experimental classes had a Kolmogorov-Smirnov sig. value > 0.05 , with the acceptance criterion H_0 , indicating that the samples originated from normally distributed research data. Furthermore, a homogeneity test was conducted, as shown in Table 9. The results of the systems thinking skills homogeneity test for the control and experimental classes had a sig. value > 0.05 , with the acceptance criterion H_0 , indicating that both experimental samples came from homogeneous populations. An independent sample t-test was then conducted. The results of the independent sample t-test are shown in Table 10. The sig. value was obtained. (2-tailed) < 0.05 , with the acceptance test criteria H_1 meaning that there is a significant difference between the average n-Gain value of the systems thinking skills of students in the experimental class and the control class, where the average n-Gain value of students in the experimental class is higher than that of the control class.

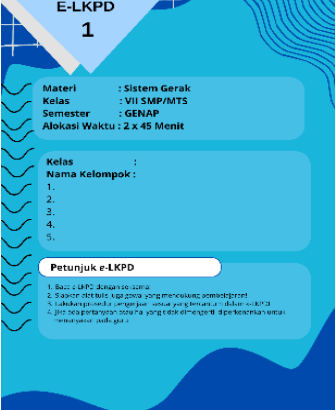
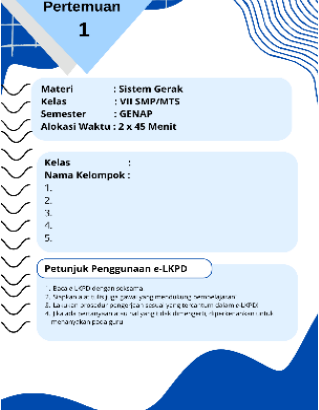
To determine the effectiveness of e-worksheets in improving students' systems thinking skills, an effect size test was conducted. Table 11 shows that the effect size (Cohen's d) value for systems thinking skills is ≥ 0.08 , which is considered a "large" effect. This indicates that the implementation of the e-worksheets representation model has a significant impact on improving students' systems thinking skills. Anggraini et al. (2022) stated that the use of multiple representation models in electronic-based learning media positively contributes to learning implementation because it helps students understand material through various forms of representation, such as visual, verbal, symbolic, and concrete. Interactive simulations provide opportunities for students to perform actions (operations) and build their understanding of a system through "operational thinking" (Richmond, 1993). Feedback from participants was very positive, with the vast majority reporting that systems thinking and simulations were beneficial to learning (Green et al., 2022).

The significant influence of the developed e-worksheets on students' systems thinking skills is because learning using the multi-representation e-worksheets model is able to make students identify system components and processes within the system,

namely in the initial knowledge phase of visual representation and the phenomenon presentation phase. In this phase, students are introduced to various visual forms such as images of normal and impaired bones and muscles, as well as videos about osteoporosis and muscle cramps. This skill reflects that students are not merely memorizing terms, but have associated visuals with functional meanings, a form of iconic representation by Bruner that leads to an initial understanding of body systems. This is in accordance with the research of Assaraf et al. (2010) which states that the initial stage of systems thinking begins with

recognizing system components visually. Constructivist, it shows the process of assimilation to their initial schema about the human body (Piaget, 1972). Visual representation functions as a stimulus that allows students to construct initial concepts independently through direct observation of differences in system structures and processes. Systems thinking skills in the hierarchy of identifying relationships between system components can be seen when students are invited to relate one component to another functionally, such as brittle bones causing fragility, or shrinking muscles causing weak movement.

Table 12. Validator's Suggestions

Information	Before Repair	After Repair
On the front page, the title of the e-worksheets multi-representation model is removed and replaced with the student worksheet and the font used is Agrandir Narrow.		
On the introduction page, it is best not to use too many colors so that the background color is white.		
On the e-worksheets identity page, e-worksheets 1 should be replaced with meeting 1, and the background color should be white. The e-worksheets instructions should be added to the usage instructions so that it becomes e-worksheets user instructions.		

Information

During exploration activities, the font size should be reduced and the exploration barcode should be combined with the exploration instructions.

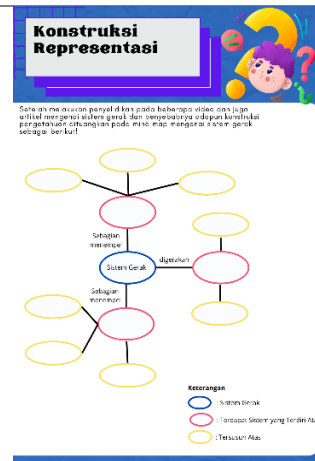
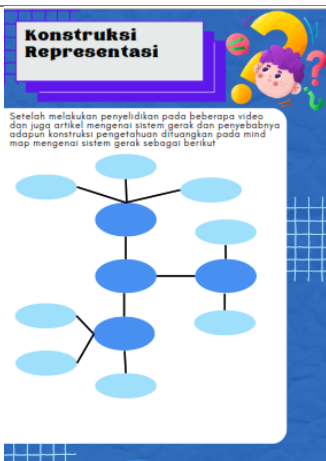
Before Repair



After Repair



In the representation construction activity, the mind map section does not show any differences between the types of writing about disorders or abnormalities in the motor system and the factors that cause disorders and sub-factors that cause disorders, so there needs to be a difference in color for each name in the mind map to make it easier for students to differentiate.



Systems thinking skills in the hierarchy of identifying dynamic relationships within a system are practiced in the key concept identification and exploration phase. Students construct complex relationships between systems, such as the motor system and the metabolic or excretory system. This process is highly symbolic, where students construct a narrative or logical flow of a phenomenon. Furthermore, students are trained to understand that systems in the body do not function separately, but are interconnected and influence one another. Students are able to explain that walking not only involves muscles and bones but also increases oxygen supply, accelerates metabolism, and ultimately helps the bone formation process, thereby preventing osteoporosis. Systems thinking skills in the hierarchy of organizing system components and processes within a framework of relationships are practiced in the construction phase. In this phase, students are asked to create a mind map showing the relationship between disorders of the motor system (e.g., osteoporosis, muscle cramps) and their causative factors (e.g., calcium deficiency, lack of exercise, dehydration). Through this mind map, students not only write down information separately but also organize it into a structured, interconnected relationship. This demonstrates that they are actively and structurally constructing knowledge, rather than simply taking

notes. The results of the mind map will demonstrate students' holistic perspective, where learning with complex systems aims to understand biological phenomena that arise from the dynamic interactions between components (Verhoeff et al., 2008). In line with this, research suggests that the use of systems-based learning media and strategies can clearly help students understand the relationships between science concepts and improve their ability to view interactions within the system as a complex whole (Hidayati et al., 2020).

The next stage is final product revision. This stage involves fixing video links that cannot be opened in the e-worksheets. The next stage is disseminating the e-worksheets product, which includes the representation model developed in the Science MGMP throughout East Lampung.

Systems thinking skills in the hierarchy, understanding cycles within the system, are practiced when students are asked to describe the flow of movement system disorders sequentially in the form of cycles. Systems thinking skills in the hierarchy, making generalizations and understanding the hidden dimensions of the system, are practiced by students constructing generalizations or general conclusions from their thinking processes. Furthermore, students can identify hidden factors within the system, such as hormones or stress, that are not immediately visible but

have a significant influence on the balance of the body's systems. This process demonstrates that students not only see explicitly visible relationships but are also able to recognize and connect latent variables (hidden dimensions) within the system. Systems learning that focuses on applying systems concepts to explore and analyze complex biological systems can train students to understand the hierarchy and cycles within the system (Verhoeff et al., 2018). Verhoeff et al. (2008) stated that students who are able to generalize from complex data demonstrate advanced systems reasoning skill. Systems thinking skills in the temporal hierarchy of thinking: retrospection and prediction. In the presentation and interpretation stages of learning, students are not only asked to explain what is happening, but also to look back (retrospection) and think ahead (prediction). This ability demonstrates that students understand cause-and-effect relationships over a period of time, not just in the present but also in seeing patterns of change over time. Emphasize that learning that integrates prediction and reflection fosters deeper systems thinking skills because it trains students to consider the long-term effects of an action or phenomenon.

Conclusion

The results of this study concluded that the development of e-worksheets representation models in improving systems thinking skills has characteristics including interactive because it is packaged in electronic form and makes it easier for students to answer questions anywhere and anytime, contains learning outcomes in accordance with the independent curriculum, and each representation model syntax contains a hierarchy of systems thinking skills. Based on these characteristics, the e-worksheets representation model developed is valid with very high criteria from the results of expert responses in terms of content suitability (95%), construction (92%), and readability (90%) and practical from the results of student responses in terms of interestingness (92%), ease (100%), readability (100%), and usefulness (100%) and educator responses in terms of interestingness (91%), ease (100%), readability (100%), and usefulness (100%). The results of the independent sample t-test stated that there was a difference in the average n-Gain value of students, where the average n-Gain of students' systems thinking skills in the experimental class was 0.71 with the "high" category while the control class was 0.32 with the "moderate" category. The results of the effect size test stated that the developed e-worksheets representation model was effective in improving students' systems thinking skills on the Motion system material with a large influence.

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Author Contributions

VIdi Ayu Winingdyah contributed to data collection, data analysis, and writing the draft of the article. Dewi Lengkana and M. Setyarini guided the implementation of the research, provided input on the draft of the article, and reviewed the article.

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Conflicts of Interest

No conflict of interest.

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