JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 10 No. 2, May 2025, Page 273-289*

Developing E-LKPD based on Creative Problem Solving to Enhance Higher Order Thinking Skills and Learner Autonomy in Topics Related to Progressive and Standing Waves

Diah Nurrachmah [1*)], Restu Widiatmono [2]
Universitas Negeri Yogyakarta, Indonesia[1,2]
[*)]Corresponding E-mail: diahnurrachmah.2022@student.uny.ac.id

Received: November 11th, 2024. Revised: February 3rd, 2025. Accepted: May 14th, 2025

Keywords :
E-LKPD; Higher Order Thinking Skills; Learner Autonomy; Progressive and Standing Waves

ABSTRACT
This study aims to produce a valid, practical, and effective E-LKPD utilizing Creative Problem Solving (CPS) approach to enhance both Higher Order Thinking Skills (HOTS) and the independent learning attitude of students in topics related to progressive and standing waves. The research method employed was Research and Development utilizing the 4-D development design model, which includes the phases: Define, Design, Develop, and Disseminate; however, Disseminate phase was not implemented. The validity of the E-LKPD CPS was assessed by material and media validators. Its practicality was evaluated based on the feasibility of implementing the E-LKPD CPS during the learning process as observed. The effectiveness of the E-LKPD CPS was determined through N-gain tests, while user response was gathered via response questionnaire. Data analysis was conducted using quantitative descriptive methods. The E-LKPD CPS was pilot-tested in a limited setting at MAN 2 Yogyakarta, involving 33 MIPA 1 as experimental group and another 33 as control group (MIPA 2). The E-LKPD CPS received validity scores of 97.47% from content experts and 95.48% from media experts, both considered very valid. Its practicality scored at 84.08% (good). The effectiveness of the E-LKPD CPS in enhancing HOTS was demonstrated with experimental group N-gain of 70.69%, compared to the control group's 63.70%, both deemed moderately effective. The effectiveness in fostering independent learning attitudes yielded N-gain of 74.28% for the experimental group and 67.23% for the control group, also rated as moderately effective. Student response was highly favorable at 91.33% (very good). Consequently, the developed E-LKPD CPS is declared valid, practical, and effective for implementation in educational settings.

INTRODUCTION

The process of learning physics involves cultivating curiosity through direct discovery by employing scientific work that utilizes facts, constructs concepts, principles, theories, and scientific methodologies. Various physical phenomena in daily life are directly observable by students; however, there are also many phenomena that are difficult to observe or realistically depict due to certain limitations. Teaching and applying physics in schools is crucial because it not only provides students with scientific knowledge but also serves as a platform for the development of scientific working skills, which are essential for solving everyday problems [1]. Physics is an experimental science used to uncover principles and patterns that link various aspects of the universe [2]. It is not merely about memorizing theories or formulas but involves deeply understanding numerous concepts [3].

Achieving proficiency in physics necessitates mastery over three fundamental aspects of the discipline: concepts, laws or principles, and theories. Mastery over these components is essential for successful engagement with physics [4]. The effectiveness of the learning process is reflected in the outcomes; high achievement levels indicate successful learning, while lower achievement levels may signal that the educational objectives have not been met. Djamarah [5] posits that the learning process is deliberately crafted to benefit students, encompassing both mental and physical engagement, thereby leading to transformative changes in behavior and attitudes. Consequently, a robust ability to conceptualize within physics is imperative for success in the field.

Several factors determine the learning outcomes in physics, including both internal and external factors. Internal factors originate from within the students themselves, whereas external factors come from outside the student's personal environment [6]. External factors might include the teaching methods employed by educators, the condition of the classroom, the atmosphere of the learning environment, available resources, and more. Internal factors, on the other hand, pertain to the characteristics of the students, which can encompass intelligence, talent, motivation, social class, level of aspiration, perceptions, attitudes, and learning styles [7]. The field of Natural Sciences, particularly physics, plays a strategic role in preparing students with the hopes of cultivating their abilities to think creatively, critically, and logically, and to have the initiative to respond to problems in their environment caused by the effects of knowledge. Critical thinking is included in the life skills essential for the 21st century that students are expected to master.

Critical thinking demands effort, care about accuracy, and a persistent attitude in any situation, including when facing difficult tasks. Individuals who possess critical thinking abilities are usually characterized by an openness to new ideas [8]. The capacity to apply critical thinking is immensely beneficial in daily life. According to Brookfield and Gormley, critical thinking skills can assist in addressing everyday life challenges as well as those encountered in professional and career contexts [9]. There has been a paradigm shift from Low Order Thinking Skills (LOTS) to HOTS, which currently forms the foundation of the learning model framework, specifically focusing on the C4, C5, and C6 levels of cognitive tasks [10]. HOTS represent a level of mental reasoning that is undeniably advanced [11]. HOTS is also regarded as a component of creative thinking abilities and critical thinking skills [12]. HOTS encompasses abilities in problem-solving, thinking, analyzing, arguing, and decision-making [13]. HOTS was first conceptualized by an author and Associate Professor from Duquesne University, named Susan M. Brookhart, in her book, “How to Assess Higher-order Thinking Skills in Your Classroom” (2010) [14].

HOTS represent the highest level in the hierarchy of cognitive processes. High-level thinking skills are closely related to cognitive, affective, and psychomotor domains, all of which integrate within the teaching and learning process [15]. In physics education, critical thinking can be implemented by aligning critical thinking skill indicators with the specific characteristics of physics learning materials. The indicators used for measurement are presented in Table 1.

Table 1. Indicators of HOTS [11]

Cognitive Process	Cognitive Process Dimensions	Knowledge Dimensions
Analyzing	Differentiating Organizing Attributing	Conceptual
Evaluating	Examining Criticizing or Assessing	Procedural
Creating	Formulating Planning Producing	Metacognitive

The term HOTS is used to describe various cognitive activities that go beyond the level of understanding and are situated below the level of application, according to Bloom's Taxonomy [12].

Empirically, students who possess HOTS can learn more effectively, develop more complete performance, and mitigate some learning deficiencies [12]. Essentially, by employing creative and innovative thinking, students are effectively applying higher-level thinking skills. The implementation of HOTS in students brings several benefits, including developing a positive attitude, enhancing motivation, and improving academic achievement [12]. In terms of enhancing learning outcomes through the use of HOTS in students, the results will be more significant if accompanied by the capability for independent learning. Learner autonomy is crucial for students to take responsibility for organizing and disciplining themselves, enabling them to develop learning abilities based on their own volition [16]. Learner autonomy is characterized by an individual's attitude in the self-learning process aimed at achieving goals that contribute actively to the learning process and not depending on others [17]. The term often used to describe learner autonomy is self-regulated learning [18].

Learner autonomy is not merely about studying alone but rather emphasizes the aspects of being active, creative, and independent in one’s learning process. The indicators of learner autonomy can be categorized into eight types: 1) thinking critically, creatively, and innovatively; 2) being uninfluenced by others; 3) facing problems capably; 4) having a deep understanding of problem-solving; 5) solving one’s own problems without seeking others' opinions; 6) possessing high self-confidence, even in situations different from others; 7) having a diligent and disciplined work ethic; 8) taking responsibility for one’s actions [19]. The level of a person’s learning autonomy in the learning process is not solely determined by the individual themselves. There are two types of factors influencing student learning autonomy: endogenous and exogenous factors. Exogenous factors include family conditions, school environment, and the surrounding community. Endogenous factors originate within the students themselves and include physiological factors such as physical condition and health, as well as psychological factors like talents, interests, independent attitudes, motivation, and intelligence [20]. In the educational process, the role of the teacher as a facilitator is critical in enhancing the exogenous factors that improve student learning autonomy.

The 2013 Curriculum (K.13), which is based on Student Centered Learning and casts the teacher as a facilitator, mandates that students be more actively involved in the learning process. To realize this active involvement of students in aiding the learning process, it is essential to employ various strategies and innovations. A learning strategy is a process that involves techniques, the selection of various methods, and steps in teaching that educators can determine to optimize students' capabilities in the learning process [21]. One strategy that teachers can implement to enhance HOTS and learner autonomy is by choosing appropriate models and learning media. The use of media supports the learning process; educational media includes all forms of objects and tools used to facilitate the learning process [22]. Examples of learning media include textbooks, modules, Student Worksheets (LKPD), and educational props [23]. Interactive LKPDs serve as one of the learning resources that can be distributed during the educational process.

The ability to foster HOTS and independent learning attitudes towards physics among students can be facilitated by implementing interactive LKPDs in their education. With technological advancements,

there has been significant innovation in educational media, particularly with interactive LKPDs that have integrated electronic features, known as E-LKPDs. E-LKPDs are interactive electronic teaching materials that include summaries of topics, instructional guidelines tailored to the content while referencing basic competencies and learning objectives [24]. The ease of accessing E-LKPD media via smartphones or computers adds a distinct appeal for users. Moreover, the innovative features of E-LKPDs, which include comprehensive and engaging elements such as images, videos, animations, and online experiments, are particularly well-suited for meeting the diverse needs and learning outcomes desired by students.

The E-LKPD developed through the Creative Problem Solving (CPS) approach, wherein the CPS model is a strategy that engages students in critical thinking and equips them with problem-solving skills. This model of creative problem solving promotes creativity in tackling challenges, a process that demonstrates competence in HOTS. The CPS learning model stimulates students to become more active in generating innovative ideas, which can then serve as solutions to the problems presented [25]. Furthermore, the implementation of the CPS model in the educational process can enhance problem-solving abilities, scientific process skills, and students' metacognitive awareness [26].

To facilitate the development of innovative interactive LKPDs, or E-LKPD, using the CPS approach, the Live Worksheet application can be utilized. This application supports the inclusion of text, images, audio, video, animations, and online experiments. Beyond employing the CPS model to enhance HOTS capabilities, the Live Worksheet website can also be used to boost motivation, independent learning, and the academic outcomes of students in physics. According to Prihandono [27], the use of an interactive E-LKPD assisted by Live Worksheet can improve critical thinking skills, evidenced by an N-gain of 53.1% (in the moderate category), with an increase in the completion rate of physics learning outcomes by 22.22%.

Research related to the development of E-LKPD using the CPS approach has been extensively conducted; however, studies specifically focusing on enhancing the HOTS capabilities and the independent learning attitudes of students on the topics of progressive and standing waves in the eleventh grade at MAN 2 Yogyakarta through the Live Worksheet website have not yet been undertaken. The choice of topics on progressive and standing waves is motivated by interviews with physics teachers, who indicated that these topics contain many concepts applicable to daily life. Nevertheless, the inadequate application of these concepts to solve real-life problems is a key factor contributing to the students' difficulties in developing their HOTS capabilities. Additionally, the use of E-LKPD CPS that includes evaluation questions within the cognitive domain of high-level critical thinking, accessible online anytime and anywhere, has not been available in the schools where the researcher conducted observations and data collection. There is also a lack of full awareness among the students regarding the attitude towards independent learning. This is evident from the students' reluctance to complete tasks based on their own initiative, often lacking confidence in their own work, although there are some students who exhibit a high awareness of independent learning, it is not yet widespread. Based on these observations, the author is motivated to develop an E-LKPD product through the CPS approach to enhance the HOTS capabilities and independent learning attitudes of students on the topics of progressive and standing waves.

METHOD

This developmental research resulted in an E-LKPD based on Creative Problem Solving (CPS) using the 4-D development process (define, design, development, disseminate), omitting the disseminate phase. The product development phase was conducted at the Faculty of Mathematics and Natural Sciences, Yogyakarta State University, within the Department of Master of Science in Physics Education. The data collection methods employed included validation, observation, testing, and survey methods. The validation method involved sending files and the developed product to validators online. Observations were made of student activities in accordance with the student activity sheets through

activities in the CPS syntax. Testing was conducted online during the learning activities in the classroom.

In this developmental study, two sample groups were utilized: one experimental class and one control class. A limited trial was conducted with 33 students from XI MIPA 1 as the experimental class and 33 students from XI MIPA 2 as the control class at MAN 2 Yogyakarta. A pre-test was administered to each sample group to assess the initial capabilities of the students. Meanwhile, a post-test was given to each group to determine the final capabilities as a benchmark for the success of the learning process after the treatment was administered. The experimental class and control class received different treatments. The experimental class was taught using the E-LKPD CPS, while the control class used traditional student worksheets and teaching modules provided by the school.

The Define phase includes five main stages: front-end analysis, learner analysis, task analysis, concept analysis, and analysis of learning objectives specifications. The front-end analysis results in a study addressing fundamental issues concerning the HOTS capabilities and the independent learning attitudes of students towards relevant learning resources. Learner analysis involves examining the characteristics of students' school life conditions to facilitate the achievement of curricular goals. Task analysis entails a review of the tasks and materials presented in learning, ensuring that the breadth of the product to be developed aligns with the utilized curriculum. Concept analysis is the stage where key concepts are identified and then systematically arranged according to relevant concepts. Analysis of learning objectives specifications is a summary of all task and concept analysis results, which then guide the learning objectives. These defined learning objectives are subsequently used as the basis for creating tests and designing the tools used in CPS-based E-LKPD learning.

The Design phase encompasses four principal stages: constructing criterion-referenced tests, media selection, format selection, and creating an initial design. The construction of criterion-referenced tests is aimed at developing data collection instruments such as validation sheets, teacher assessment sheets, pre-test and post-test questions, student response questionnaires, and questionnaires on students' independent learning. Media selection is carried out to determine the most suitable media based on the quality of the students and the objectives for item enhancement. Format selection serves as a foundation for the content writing in the developed product to ensure alignment with the syntax of the adopted learning model. Creating an initial design involves developing teaching modules, data collection instruments, and the E-LKPD CPS product. The aspects included in the E-LKPD CPS are developed to enhance the HOTS capabilities and the independent learning attitudes of the students.

The Development phase involves the implementation of the E-LKPD CPS with eleventh-grade science students (MIPA) at MAN 2 Yogyakarta, scheduled for March to April 2024. Two classes, each comprising 33 students, will participate, with one serving as the experimental group and the other as the control group. The instruments employed include the E-LKPD CPS validation sheet, student activity observation sheet, HOTS-based pre-test and post-test questions, independent learning attitude questionnaire, and a student response questionnaire. The validity of the E-LKPD CPS will be determined using validation sheets completed by expert media validators and content validators, which will then be analyzed using the following Likert scale.

$$\overline{X} = \frac{\Sigma X}{n} \quad (1)$$

The next step involves converting the average score of each aspect into a qualitative product quality level, using ideal conversion guidelines. Here are the steps to calculate the ideal average as follows.

$$\overline{X}_i = \frac{1}{2} \text{ ideal maximum score} + \text{ideal minimum score} \quad (2)$$

Ideal maximum score = Σ Criteria Item×Highest Score
Ideal minimum score = Σ Criteria Item×Lowest Score

Subsequently, the ideal standard deviation is calculated using the formula outlined below.

$$\text{SBi} = \frac{1}{6}(\text{ideal maximum score} - \text{ideal minimum score}) \quad (3)$$

Based on the values obtained from the calculations using the formula above, the next step is to determine the assessment criteria using the Likert scale as follows.

Table 2. Likert Scale Assessment Criteria

No	Score Interval	Category
1	$\bar{X} > \bar{X}_i + 1{,}8\,SBi$	Excellent
2	$\bar{X}_i + 0{,}6\,SBi < \bar{X} \leq \bar{X}_i + 1{,}8\,SBi$	Good
3	$\bar{X}_i - 0{,}6\,SBi < \bar{X} \leq \bar{X}_i + 0{,}6\,SBi$	Fair
4	$\bar{X}_i - 1{,}8\,SBi < \bar{X} \leq \bar{X}_i - 0{,}6\,SBi$	Poor
5	$\bar{X} \leq \bar{X}_i - 1{,}8\,SBi$	Very Poor

The validation conducted by validators to assess the validity of an E-LKPD CPS product is based on the results from the validation sheet of material experts and media experts, and is analyzed using the following formula.

$$\text{Ideal Percentage} = \frac{\text{Average score}}{\text{Ideal maximum score}} \times 100\% \quad (4)$$

The E-LKPD CPS can be declared valid or excellent for use if the calculations on the Likert scale indicate that the average value is greater than $\bar{X}_i + 1{,}8\,SBi$, with an ideality percentage of ≥70% in a category modified by Riduwan [28].

The effectiveness of the E-LKPD CPS product is assessed based on students' cognitive learning outcomes, HOTS capabilities, and attitudes towards independent learning. The completeness of the students' learning outcomes is determined based on cognitive test results and HOTS capability indicators, which are considered complete or meet the minimum passing grade (KKM) set by the school, which is ≥75. Subsequently, calculations can be performed using the following equation.

$$\text{Ideal Percentage} = \frac{\text{Average score}}{\text{Ideal maximum score}} \times 100\% \quad (5)$$

The E-LKPD CPS is considered effective, in the sense that it can enhance HOTS capabilities and attitudes towards independent learning, if the calculations on the Likert scale show that the average value is greater than $\bar{X}_i + 1{,}8\,SBi$. This is with an ideality percentage of ≥70% according to a modification table from Riduwan [29].

The practicality of the E-LKPD CPS product is determined based on observation results of student activities or the implementation observance. The assessment results of the implementation effectiveness of the E-LKPD CPS product can be observed during the learning process stages in the form of Likert Scale answer choices from 1 to 4. Subsequently, the observation results of the product's practicality based on these observations can be calculated using the following formula.

$$\text{Ideal Percentage} = \frac{\text{Average score}}{\text{Ideal maximum score}} \times 100\% \quad (6)$$

The E-LKPD CPS can be considered practical for use if the average percentage obtained is greater than the value $\bar{X}_i + 1{,}8\,SBi$, with an ideality percentage of ≥70% based on a modification table from Riduwan [28].

The responses of the students are obtained based on the results of the response questionnaire administered after participating in the learning implementation using E-LKPD CPS. The student

response questionnaire consists of 22 questions covering four aspects with answer choices using a Likert scale from 1 to 4. Subsequently, the results of the students' responses on the questionnaire can be calculated using the following formula.

$$\text{Ideal Percentage} = \frac{\text{Average score}}{\text{Ideal maximum score}} \times 100\% \quad (7)$$

The E-LKPD CPS developed is declared effective and suitable for use if the average percentage is greater than the value $\bar{X}_i + 1{,}8\ SBi$, with an ideality percentage of ≥76% based on a modification table from Riduwan [28].

Subsequently, an N-gain test is conducted on the learning outcomes of the students. The purpose of the N-gain test is to determine the extent of improvement in the HOTS abilities of students as a result of the implementation of E-LKPD CPS in the experimental class and its absence in the control class. The N-gain test is performed using the following formula.

$$\text{N} - \text{gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{ideal score} - \text{pretest score}} \quad (8)$$

The criteria for the results from the N-gain are determined based on Table 3.

Tabel 3. Criteria for N-gain Levels [30]

Percentage (%)	Interpretation
> 76	Effective
56-75	Moderately Effective
40-55	Less Effective
> 40	Not Effective

RESULTS AND DISCUSSIONS

The E-LKPD CPS product produced in this research consists of E-LKPD through a creative problem solving (CPS) approach to enhance the Higher Order Thinking Skills (HOTS) and the attitude of independent learning in students regarding the topics of traveling waves and stationary waves, covering two topics. Topic 1 in E-LKPD CPS covers the material on traveling waves, while Topic 2 focuses on the material about free-end and fixed-end stationary waves.

Each topic contains several syntaxes in accordance with the adopted learning model, which is the CPS model, accompanied by discourse and narratives that are highly relevant to the development of HOTS. The sections of the E-LKPD CPS include a front cover featuring the title along with the identities of the students, table of contents, a brief description, instructions for using the E-LKPD, content standards, concept maps, topics, learning objectives, pre-test questions, case studies in the syntax of objective finding, fact finding, learning materials according to the topic, problem finding, idea finding, solution finding, acceptance finding, post-test questions, and references. The indicators of HOTS tested include analyzing, evaluating, and creating, specifically in learning activities outside of written tests [31]. Meanwhile, the attitude of independent learning includes various indicators tested among the students, such as self-confidence, the ability to appreciate and manage time well, work independently, be responsible, and possess skills and expertise appropriate to their field [32].

The E-LKPD CPS was developed using the website www.liveworksheets.com, and its usage and operation require an internet/online connection. This E-LKPD CPS can be accessed through smartphones, laptops, and computers, but initially requires loading or registering an account using individual Gmail accounts. The unique packaging of this E-LKPD CPS is similar in form to online worksheets, and students can directly fill in the answer columns beneath the questions displayed. In contrast with printed LKPDs, their use is considered less practical since they are still in book form,

making them less effective and efficient as they only contain materials, images, and discussion or question sheets. The E-LKPD CPS not only contains student worksheets but also includes various types of videos, images, and online lab simulations using PhET simulations, aimed at supporting students' understanding of the content provided. The live worksheets site used in the development of this E-LKPD CPS product offers two different types of access according to its function. Students can access the complete E-LKPD CPS via the student site, while teachers can access it through the teacher class site. This application is one of the types that is easy to use in creating E-LKPD CPS because it is simple and free. Below are presented several views on the E-LKPD CPS sheets and their components in Table 4.

Table 4. The Display of the LKPD CPS (Creative Problem Solving)

No	Display	Description
1.		The Cover of the E-LKPD on the Topic of Traveling and Stationary Waves in CPS (Creative Problem Solving). It serves as the front cover, providing an overview of the content. It includes a section for users to fill in their personal information.
2.		The introductory page before proceeding to the first syntax of the learning activities. This page contains a video to motivate and stimulate students' enthusiasm for learning, as well as to provide an initial overview of the material to be studied. It also includes pre-test exercises to assess students' initial understanding.
3.		The E-LKPD page in the objective finding syntax serves as the first activity sheet, presenting case studies of everyday phenomena related to the topics (Topic 1: Traveling Waves, and Topic 2: Stationary Waves).

No	Display	Description
4.		The second syntax in the E-LKPD is fact finding, which is a group discussion worksheet containing several fact-finding questions related to the case studies from the previous syntax.
5.		The E-LKPD page in the problem finding syntax includes an independent virtual experiment, followed by several questions and an analysis of problem identification related to the case studies from the objective finding syntax page.
6.		The next learning activity sheet contains the idea finding syntax. Idea finding involves discovering solutions that can be used to address the problems formulated on the previous syntax sheet.
7.		The solution finding syntax sheet contains the final idea design, which is considered highly effective as a solution to the problems that have been formulated.

No	Display	Description
8.		The acceptance finding syntax sheet serves as a conclusion and description of the developed idea, along with observations on its implementation to determine whether it effectively serves as a solution or not. It also acts as a validation of the hypothesis made against the experimental results.
9.		The final sheet in the E-LKPD CPS contains multiple-choice and essay post-test questions focusing on the cognitive domains of C4 and C5. These questions aim to assess students' cognitive learning outcomes, particularly their Higher-Order Thinking Skills (HOTS).

The Validation of CPS E-worksheet

Two expert lecturers serve as validators: one for content and the other for media, to validate the E-LKPD CPS product. The components included in content validation consist of aspects such as construction, substance, language, and evaluation. The component indicators for media validation encompass graphics, media operation, and language use. The recap of the content validation results can be found in Table 5, while the validation results for media aspects are presented in Table 6.

Table 5. The recap of the content validation results of E-LKPD CPS

No	Aspects	Mean (%)	Category
1.	Substance	98,62 %	Highly Valid
2.	Construction	100 %	Highly Valid
3.	Language	97,5 %	Highly Valid
4.	Evaluation	93,75 %	Highly Valid
Mean of Material Validity		**97,47 %**	Highly Valid

Tabel 6. The recap of E-LKPD CPS Media Validation Results

No	Aspects	Mean (%)	Kategori
1.	Graphics	96,43 %	Highly Valid
2.	Media Operation	92,5 %	Highly Valid
3.	Language Use	97,5 %	Highly Valid
Mean of Media Validity		**95,48 %**	**Highly Valid**

Based on Table 5, the data from the content validation by the expert validators yielded a mean score of 97.47%, categorized as highly valid. Therefore, it can be concluded that the developed E-LKPD CPS, aimed at enhancing students' HOTS and independent learning attitudes in the topics of traveling waves and stationary waves, is valid and of high quality for implementation.

In Table 6, the data from the media validation by the expert validators revealed a mean score of 95.48%, categorized as highly valid. Therefore, it can be concluded that the developed E-LKPD CPS, designed to enhance students' HOTS and independent learning attitudes in the topics of traveling waves and stationary waves, has overall media quality that is valid and highly suitable for implementation.

The Practicality of CPS E-Worksheet

The application of the E-LKPD CPS to high school students aims to assess the product's practicality for users. The implementation results of the E-LKPD CPS were conducted with 30 participants, consisting of 28 students from class XI at MAN 2 Yogyakarta and 2 physics teachers. The product's practicality was assessed based on observations made during group discussions and independent activities using the E-LKPD CPS in the classroom. Several aspects were used as measurement indicators to evaluate the practicality of the E-LKPD CPS, including content, presentation, graphics, and language. The recap of the practicality results of the E-LKPD CPS based on student feedback can be found in Table 7.

Table 7. The recap of the practicality results of the E-LKPD CPS

No	Aspects	Mean (%)	Category
1.	Content	85,22 %	Good
2.	Presentation	82,96 %	Good
3.	Graphics	83,7 %	Good
4.	Language	84,42 %	Good
Mean of Media Practicality		**84,08 %**	**Good**

Table 7 displays the percentage scores for the practicality of the developed E-LKPD CPS based on feedback from users, including students and physics teachers. The overall practicality score mean is 84.08%, categorized as good for implementation and use. This score indicates that the E-LKPD CPS, with all group and independent activities aligned with the CPS syntax, can be executed very well by students. This finding aligns with statements regarding the integration of the CPS model into the E-LKPD, which is highly practical for students as it significantly enhances cognitive learning outcomes in science subjects [33]. The implementation of the E-LKPD, oriented toward problem-based learning models, is also very practical as it can be accessed using smartphones, laptops, or computers [34].

The practicality of the E-LKPD CPS from aspects such as content, construction, language, and even the system of use and operation is deemed practical because it is flexible; users can access it anywhere and anytime with an internet connection. The E-LKPD CPS is very practical to use as it does not confuse or overwhelm students in understanding the material and all the group discussion activities, whether collaborative or independent, as it is tailored to the cognitive ability levels of the students. Another fact is that after students follow and complete tasks for each activity in the E-LKPD CPS in a sequential manner, it indicates that they have mastered Higher-Order Thinking Skills (HOTS) and have successfully developed a sense of independent learning.

The Effectiveness of E-LKPD CPS

The E-LKPD CPS can be considered effective if it successfully enhances learning outcomes in terms of cognitive learning indicators, HOTS skill acquisition, and students' attitudes toward independent learning in the topics of traveling waves and stationary waves.

1. Cognitive Learning Outcomes

The cognitive learning outcomes were measured using test instruments administered through pre-tests and post-tests to 33 students. The pre-test instrument consisted of 20 multiple-choice questions, while the post-test included 20 multiple-choice questions and 6 essay questions, targeting the C4 and C5 cognitive domains according to Bloom's taxonomy. Both the experimental and control classes were given the same test instruments, but there were differences in the implementation of teaching media and learning models. The control class employed conventional teaching models used by teachers at

school, such as inquiry, discussion, and question-and-answer sessions, with instructional materials based on LPKD and printed modules available at the school. In contrast, the experimental class received different treatment, utilizing the E-LKPD CPS as instructional material and HOTS questions, with a learning model that aligned with the CPS syntax. The data obtained from the cognitive test instruments for both classes can be seen in Table 8.

Table 8. The Recap of Students' Cognitive Learning Outcomes

Students	Experimental Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
A001	37,25	77,50	41,25	71,75
A002	41,55	81,25	42,75	58,25
A003	31,75	82,50	43,50	62,75
A004	38,25	80,00	42,25	66,50
A005	37,55	81,25	41,75	48,25
A006	38,50	67,50	38,75	68,50
A007	38,77	73,75	38,25	76,25
A008	31,25	70,25	29,25	68,50
A009	33,75	75,75	30,75	52,75
A010	38,75	91,25	30,25	63,25
A011	37,25	64,75	32,25	53,25
A012	44,75	78,50	44,50	68,75
A013	33,75	82,00	41,00	66,25
A014	29,75	67,25	38,75	56,25
A015	27,50	82,75	36,75	58,75
A016	51,35	71,75	35,50	56,50
A017	40,00	57,50	33,75	70,50
A018	23,75	75,75	36,50	55,75
A019	41,35	71,25	37,50	58,26
A020	48,25	78,75	40,75	66,50
A021	26,25	71,75	37,50	61,75
A022	32,25	78,25	35,75	53,75
A023	47,50	72,50	36,25	57,75
A024	42,50	85,25	37,75	65,50
A025	37,50	92,25	33,25	65,75
A026	41,25	61,00	31,75	57,50
A027	47,50	85,50	35,25	60,25
A028	42,50	85,25	34,50	62,75
A029	37,50	72,75	34,75	66,75
A030	31,25	78,75	39,50	51,50
A031	32,75	82,50	36,50	62,75
A032	37,50	67,75	40,75	72,25
A033	41,75	78,50	32,50	62,50
Mean	**37,67**	**76,46**	**37,03**	**62,07**

Table 8 shows a significant increase in cognitive scores, particularly in the experimental class, which had a mean score of 76.46. In contrast, the control class also experienced an increase in cognitive scores, but it was not as significant, with a mean score of 62.07. This indicates that the E-LKPD CPS is effective in enhancing cognitive learning outcomes in the topics of traveling waves and stationary wave.

2. HOTS Learning Outcomes

The learning outcomes for students' HOTS in the topics of traveling waves and stationary waves can be assessed using the pretest and posttest question sheets. The posttest instrument measuring HOTS capabilities includes both multiple-choice and essay questions. The data from the pretest and posttest

were then analyzed using the N-gain test. The N-gain test aims to determine the improvement in students' HOTS abilities. The recap of the HOTS learning outcomes for the students is presented in Table 9.

Tabel 9. The results of N-gain test HOTS

Class	*Pre-test*	*Post-test*	*N-gain* (%)	Category
Experimental	37,67	76,46	70,69 %	Fairly Effective
Control	37,03	62,07	63,76 %	Fairly Effective

Based on Table 9, the N-gain test results for both the experimental and control classes indicate a criterion of fairly effective. However, the experimental class achieved a higher N-gain score of 70.69% compared to the control class, which scored 63.76%. This difference can be attributed to the varying treatments and instructional materials used during the learning process provided by the teacher to the students. The N-gain results demonstrate that the E-LKPD CPS, supported by live worksheets, is quite effective as a learning media to enhance students' HOTS capabilities.

This is evidenced by statements regarding the implementation of the CPS learning model, which significantly supports the enhancement of cognitive abilities in students, particularly in higher-order thinking skills (HOTS) [25]. The CPS learning model has a positive and significant impact on students' critical thinking abilities when solving HOTS questions. The belief that the CPS model is effective in improving HOTS cognitive skills and students' motivation to learn, and that this model is among the most superior compared to other learning models, is a true statement supported by evidence of its success [35].

3. Learning Independence Outcomes

The scores for students' attitudes toward learning independence were obtained from a questionnaire administered to 33 students. The learning independence attitude questionnaire consisted of 20 items using a 1-4 Likert scale. Both the experimental and control classes used the same questionnaire; however, there were differences in the implementation of teaching media and learning models. The control class employed conventional teaching models used by teachers, such as inquiry, discussion, and question-and-answer sessions, with instructional materials based on LKPD and printed modules available at the school. In contrast, the experimental class received different treatment, utilizing the E-LKPD CPS as instructional material along with a learning model that aligned with the CPS syntax. The data obtained from the learning independence attitude questionnaire for both classes can be seen in Table 10.

Table 10. The recap of Students' Learning Independence Outcomes

Students	Experimental Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
A001	46,50	74,50	56,33	72,17
A002	50,33	78,83	53,67	78,33
A003	44,33	68,50	54,83	72,50
A004	54,17	75,33	49,17	67,17
A005	50,33	75,67	49,25	73,50
A006	50,83	71,17	57,50	76,33
A007	56,50	75,83	49,75	78,67
A008	50,83	80,83	56,50	72,17
A009	56,00	82,50	50,83	69,50
A010	49,17	74,67	53,33	74,50
A011	57,50	79,17	45,83	73,17
A012	43,33	78,17	52,83	74,83
A013	48,33	77,83	54,50	75,17
A014	52,50	73,67	50,50	70,33
A015	50,00	83,50	53,50	68,83

Students	Experimental Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
A016	55,00	70,50	48,17	84,67
A017	48,33	85,33	50,87	81,17
A018	51,33	75,00	52,00	76,17
A019	46,50	79,17	46,50	69,67
A020	55,00	86,83	54,17	73,33
A021	49,17	75,67	52,33	73,83
A022	50,83	77,17	50,00	80,33
A023	46,67	78,67	50,33	75,17
A024	44,17	75,50	51,50	76,83
A025	45,83	81,67	48,33	66,50
A026	49,17	77,50	48,75	77,67
A027	52,50	76,33	55,75	73,17
A028	48,83	80,83	51,85	72,75
A029	53,33	80,50	51,75	78,33
A030	47,50	77,50	46,77	71,75
A031	53,33	83,33	51,33	71,53
A032	48,67	70,50	59,33	75,50
A033	52,50	74,00	55,83	68,50
Mean	**50,38**	**77,46**	**51,94**	**74,06**

Table 10 shows an increase in students' attitudes toward learning independence, particularly in the experimental class, which had a mean score of 77.46. In contrast, the control class also experienced an improvement compared to their pretest scores, with a posttest mean of 74.06. Although the difference in scores from the questionnaire reflecting students' attitudes toward learning independence between the experimental and control classes is not very significant, overall, the treatment involving the use of the E-LKPD CPS effectively enhances students' attitudes toward learning independence compared to not using the E-LKPD CPS.

The pretest and posttest data from the learning independence attitude questionnaire were then analyzed using the N-gain test. The N-gain test aims to determine the improvement in students' attitudes toward learning independence. The recap of students' learning independence scores can be seen in Table 11.

Table 11. The Result of N-gain test on Students Learning Independence

Class	***Pre-test***	***Post-test***	***N-gain* (%)**	**Category**
Experimental	50,28	77,46	74,28 %	Fairly Effective
Control	51,94	74,06	67,23 %	Fairly Effective

Based on Table 11, the results of the N-gain test from the experimental and control classes indicate a criterion of sufficient effectiveness. However, the experimental class achieved a higher N-gain score of 74.28% compared to the control class, which had a score of 67.23%. This difference arises from the varied treatment applied during the learning process provided by the teacher to the students. The N-gain test results demonstrate that the E-LKPD CPS, supported by live worksheets, is quite effective as a learning medium for enhancing students' attitudes toward learning independence.

The effectiveness of using the E-LKPD to enhance students' attitudes toward learning independence is evidenced by a statement indicating that the increase in students' learning independence after participating in lessons using multimedia-based E-LKPD falls within the medium category of standard gain [36].

4. Students' Responses

Student responses to the E-LKPD CPS learning medium are an important aspect of product effectiveness as perceived by users. The mean of student responses to the developed and implemented

E-LKPD CPS in the learning activities for high school students (SMA/MA) is 91.33%, categorized as very good. This data indicates that students had a favorable and positive response during the use of the E-LKPD with the CPS learning model, which aimed to enhance HOTS (Higher Order Thinking Skills) and promote independent learning attitudes on the topics of wave motion and stationary waves. More detailed data on student responses can be found in Table 12 below.

Table 12. Students' Response on E-LKPD CPS

No	Aspects	Mean (%)	Category
1.	Content	90 %	Very Good
2.	Presentation	89 %	Very Good
3.	Language	95 %	Very Good
	Mean	**91,33 %**	**Very Good**

This is very much in line with the data in Table 12, which shows that each aspect received a positive response, categorized as very good. The content within the E-LKPD CPS significantly influences student responses, with case study topics presented based on real-life phenomena in their surroundings. This relevance stimulates students' motivation, allowing them to grasp the meaning of the concepts being studied in a real-world context. The increase in student motivation naturally impacts their engagement in the learning process, directly honing their Higher Order Thinking Skills (HOTS) in physics.

Although the E-LKPD CPS product serves as an engaging learning medium that captures students' interest, teachers should remain mindful that not all students are comfortable using technology to express their ideas or as a learning resource. Some students may feel that the E-LKPD CPS does not enhance their HOTS and independent learning skills. Therefore, when such situations arise, the teacher's role should be flexible to seek alternative solutions to ensure that the learning objectives are met. In reality, students can learn through various methods to achieve their learning goals.

CONCLUSION AND SUGGESTION

Based on the data collection results, analysis, and discussions presented in the development of the E-LKPD CPS product aimed at enhancing HOTS and independent learning attitudes among 11th-grade students in SMA/MA on the topics of progressive and stationary waves, the conclusions drawn are that the product is valid and can be effectively utilized. The developed E-LKPD CPS, created through the Live Worksheet website, has been evaluated as valid and suitable for implementation among students, both in classroom learning and individual study outside the classroom. This suitability is supported by data obtained from assessments by material and media validators. The assessment results from the material expert validator indicate a score of 97.47%, categorized as highly valid, while the assessment from the media expert validator yielded a score of 95.48%, also classified as highly valid. The developed E-LKPD CPS, created through the Live Worksheet website, has been assessed as practical for use in teaching and learning activities in the classroom as well as for independent study outside the classroom. This practicality is evidenced by user assessment data collected during implementation, which shows a score of 84.08%, categorized as good or practical. The developed E-LKPD CPS has been assessed as effective in enhancing students' Higher Order Thinking Skills (HOTS). This effectiveness is supported by the N-gain score of 70.69%, categorized as moderately effective. In comparison, the control class, which did not utilize the E-LKPD CPS learning media, achieved an N-gain score of 63.76%, also categorized as moderately effective, but still lower than that of the experimental class. Regarding self-directed learning attitudes, the experimental class recorded an effectiveness score of 74.28%, while the control class scored 67.23%. The difference in scores between the two classes indicates no significant impact on students' self-directed learning attitudes. Additionally, students' responses to the developed E-LKPD CPS were rated as very good, with an N-gain score of 91.33%. Based on the results of the research and the development of the E-LKPD CPS product that has been successfully implemented for students, the suggestions that the researcher can

provide for future improvements include the development of different materials to further understand the impact of using E-LKPD CPS on other subjects. Additionally, further research should be conducted with a larger number of students.

REFERENCES

[1] Giancoli., & Douglas, C. (2001). *Fisika Jilid 2, diterjemahkan oleh Yuhilza Hanum dari Physics Fifth Edition*. Jakarta: Penerbit Erlangga.
[2] Hasibuan, F. A., & Abidin, J. (2019). Upaya Peningkatan Pemahaman Konsep Fisika Mahasiswa Melalui Media Pembelajaran Berbasis PhET Simulation. *Jurnal Pendidikan Fisika*, *8*(2), 102-108.
[3] Saputra, R., Susilawati, S., & Verawati, N. N. S. P. (2020). Pengaruh penggunaan media simulasi phet (physics education technology) terhadap hasil belajar fisika. *Jurnal Pijar Mipa*, *15*(2), 110-115.
[4] Hapsoro, C. A., & Susanto, H. (2011). Penerapan pembelajaran problem based instruction berbantuan alat peraga pada materi cahaya di SMP. *Jurnal Pendidikan Fisika Indonesia*, *7*(1).
[5] Djamarah. (2008). *Prestasi Belajar dan Pembelajaran*. Jakarta: Cipta Karya.
[6] Ningsih, M. A., & Islami, N. (2023). Efektivitas Aplikasi PhET untuk Meningkatkan Hasil Belajar Kognitif pada Materi Gelombang Berjalan dan Gelombang Stasioner. *Jurnal Penelitian Pendidikan Fisika*, *8*(4), 290-296.
[7] Widayanti, N. I. (2010). Upaya Peningkatan Hasil Belajar IPA Tentang Tumbuhan Melalui Metode Pembelajaran Out Door Study Bagi Siswa Kelas II di SD Negeri Cemara Dua No 113 Surakarta Tahun 2009/2010. *Skripsi S-1 Progdi PGSD. Surakarta: FKIP Universitas Muhammadiyah Surakarta (tidak diterbitkan)*.
[8] Ahmatika, D. (2016). Peningkatan kemampuan berpikir kritis siswa dengan pendekatan inquiry/discovery. *Euclid*, *3*(1).
[9] Brookfield, S. D. (2011). *Teaching for critical thinking: Tools and techniques to help students question their assumptions*. John Wiley & Sons.
[10] Listiani, W., & Rachmawati, R. (2022). Transformasi taksonomi bloom dalam evaluasi pembelajaran berbasis HOTS. *Jurnal Jendela Pendidikan*, *2*(03), 397-402.
[11] Choiroh, S. S., Prastowo, S. H. B., & Nuraini, L. (2022). Pengaruh Penggunaan E-LKPD Interaktif Berbantuan Live Worksheets terhadap Kemampuan Berpikir Kognitif HOTS Fisika Siswa SMA. *Jurnal Ilmiah Pendidikan Fisika*, *6*(3), 694-705.
[12] Suparman, U. (2021). *Bagaimana meningkatkan kemampuan berpikir tingkat tinggi (HOTS) peserta didik*. Bandarlampung: Pusaka Media.
[13] Fani, K. (2021). Analisis Kemampuan Siswa Dalam Menyelesaikan Soal HOTS Pada Pelajaran IPA. *Genderang Asa: Journal of Primary Education*, *2*(2), 66-75.
[14] Sofyan, F. A. (2019). Implementasi HOTS pada kurikulum 2013. *INVENTA: Jurnal Pendidikan Guru Sekolah Dasar*, *3*(1), 1-9.
[15] Ariyana, Y., Pudjiastuti, A., Bestary, R., & Zamroni. (2018). *Buku Pegangan Pembelajaran Berorientasi pada Keterampilan Berpikir Tingkat Tinggi Program Peningkatan Kompetensi Pembelajaran Berbasis Zonasi*. Direktorat Jendral Guru dan Tenaga Kependidikan.
[16] Sulistiyo, A., Kusumawati, N., & Chasanah, L.U. (2022). *Inovasi Pembelajaran dan Tumbuhnya Kemandirian Belajar*. Jawa Tengah: Eureka Media Aksara.
[17] Dewi, N., Asifa, S. N., & Zanthy, L. S. (2020). Pengaruh kemandirian belajar terhadap hasil belajar matematika. *PYTHAGORAS: Jurnal Program Studi Pendidikan Matematika*, *9*(1), 48-54.
[18] Daulay, N. (2021). Motivasi dan kemandirian belajar pada mahasiswa baru. *Al-Hikmah: Jurnal Agama Dan Ilmu Pengetahuan*, *18*(1), 21-35.
[19] Asrori., & Thoha, C. (2020). *Psikologi Pendidikan Pendekatan Multidisipliner (1st Ed)*. CV. Pena Persada.
[20] Bukit, S., Perangin-Angin, R. B. B., & Murad, A. (2022). Strategi guru dalam menumbuhkan kemandirian belajar siswa sekolah dasar. *Jurnal Basicedu*, *6*(5), 7858-7864.
[21] Hasriadi. (2022). *Strategi Pembelajaran*. Yogyakarta: Mata Kata Inspirasi.

[22] Batubara, H. H. (2020). *Media Pembelajaran Efektif*. Semarang: Fatawa Publishing.
[23] Safitri, O. N. (2022). Pengembangan Media Bahan Ajar E-LKPD Interaktif Menggunakan Website Wizer. me pada Pembelajaran IPS Materi Berbagai Pekerjaan Tema 4 Kelas IV SDN Tanah Kalikedinding II. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, *10*(1), 86-97.
[24] Suryandari, Y., Hendrayan, A., & Hariyadi, R. (2023). Pengembangan media e-lkpd berbasis liveworksheet untuk meningkatkan kemandirian belajar siswa pada mata pelajaran pendidikan agama islam. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *8*(3), 700-707.
[25] Maheva, Z. P., Sundari, P. D., Mufit, F., & Dewi, W. S. (2023). Deskripsi Keunggulan Model Creative Problem Solving Terhadap Kemampuan Berpikir Tingkat Tinggi (HOTS) Peserta Didik. *Jurnal Pendidikan Tambusai*, *7*(2), 17910-17919.
[26] Muhali, M. (2021). Pengaruh Implementasi model creative problem solving terhadap peningkatan kemampuan pemecahan masalah, keterampilan proses sains, dan kesadaran metakognisi peserta didik. *Lensa: Jurnal Kependidikan Fisika*, *9*(1), 45-57.
[27] Prihandono, T., Supriyono, A., Meilina, I. L., & Ernasari, E. (2023). Penerapan E-LKPD Interaktif Berbasis Problem Based Learning Berbantuan Liveworksheets untuk Meningkatkan Kemampuan Berpikir Kritis dan Hasil Belajar Fisika. *Jurnal Pembelajaran Fisika*, *12*(3), 114-126.
[28] Riduwan. (2013). *Skala Pengukuran Variabel-variabel Penelitian*. Bandung: Alfabeta
[29] Riduwan. (2013). *Skala Pengukuran Variabel-variabel Penelitian*. Bandung: Alfabeta
[30] Hake, H. (1999). *Analyzing charge Gain Scores*. America Educational Research Assosiation's Division, Measurrement and Research Methodology.
[31] Anderson., & Krathwohl. (2002). *Revisi Taksonomi Bloom*. Jakarta: Rineka Cipta.
[32] Suciono, W. (2021). *Berpikir kritis (tinjauan melalui kemandirian belajar, kemampuan akademik dan efikasi diri)*. Penerbit Adab.
[33] Rawanda, T., & Hakim, L. (2024). Pengembangan E-LKPD Berbasis Creative Problem Solving Berbantuan Liveworksheets Materi Perubahan Wujud Benda Untuk Meningkatkan Kreativitas Siswa. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *9*(3), 1248-1260.
[34] Panjaitan, S. N., Mansyur, A., & Syahputra, H. (2023). Pengembangan LKPD elektronik (e-LKPD) berbasis problem-solving untuk meningkatkan kemampuan pemecahan masalah matematis dan kemandirian belajar peserta didik SMP IT Indah Medan. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *7*(2), 1890-1901.
[35] Mandey, A. F., Tilaar, A. L. F., & Tumalun, N. K. (2023). Efektivitas model pembelajaran creative problem-solving terhadap kemampuan siswa menyelesaikan soal HOTS di SMP negeri 2 Langowan kelas VIII. *Math Didactic: Jurnal Pendidikan Matematika*, *9*(3), 541-551.
[36] Palupi, F. R., & Pujianto, P. (2021). Pengembangan Lembar Kerja Peserta Didik Elektronik (E-LKPD) Berbasis Multimedia Guna Meningkatkan Penguasaan Materi Fisika dan Kemandirian Belajar Peserta Didik SMA. *Jurnal Pendidikan Fisika*, *8*(3).