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Validity Analysis of Stem-Based E-LWS with PBL Model on Motion Kinematics Material to Support Critical Thinking Skills of Senior High Scshool Students

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ABSTRACT

This research is motivated by the rapid development of technology from various fields, one of which is in the field of education. In the world of education, this technology has an important role in the continuity of the learning process. The use of electronic-based teaching materials is one of the utilization of technology in the learning process. One of the teaching materials that can be used is the Electronic Learner Worksheet (E-LWS). The purpose of the research is to make STEM-based electronic student worksheets with PBL models on motion kinematics material to support the critical thinking skills of SMA/MA students. The creation of Learner Worksheets is expected to be not only valid in terms of content and structure but also effective in facilitating a more meaningful learning experience for students. This research used the Research and Development (R&D) method. The validation process was carried out by three physics lecturers from Padang State University (UNP). Analysis of the results of the validation instrument showed that the developed Learner Worksheet obtained a validation score of 0.95. The score obtained is included in the "valid" category. Therefore, the product made in this study STEM-based Learner Worksheets with PBL model is considered valid and suitable for use as one of the innovative teaching materials to support students' critical thinking skills in understanding motion kinematics material.

Keywords: E-LWS, STEM, PBL, Critical thinking skills.

I. INTRODUCTION

The development of science and technology today is evidence of the development of human thinking in the era of revolution 4.0. Technology in the world has developed very rapidly and has an impact on everyday life [1]. The development of technology in the era of globalization has significantly pushed the pace of modern life and raised various challenges in various fields, including in education. Easy access to information and communication allows people to interact anytime and anywhere without being limited by time. Amidst this progress, people's dependence on information technology is increasing and extends to all aspects of life. In the context of education, this development encourages the birth of learning innovations that are oriented towards student centered learning. This kind of learning places students as the center in the learning process [2]. In the learning process, learners are given more space to actively participate and engage directly. Thus, learners are encouraged to explore and find information independently, while the teacher acts as a facilitator who guides and supports the learning process.

Learning in the era of technology 4.0 refers to changes in learning approaches that are carried out by utilizing the latest technology [3]. The rapid development of technology in recent years has opened up new opportunities in education, allowing educators and learners to take advantage of the latest technological innovations in learning activities [4]. Digital learning offers many opportunities to improve access and quality of education. With the right use of technology and adequate support, digital learning can be an effective solution to current educational trends [5]. Technologies such as digital simulations, problem-based applications, and online discussion platforms encourage learners to engage in higher-order thinking processes, such as examining arguments, drawing

conclusions, and providing solutions to problems. By utilizing technology appropriately, the learning process not only becomes more engaging, but also effective in fostering critical thinking skills that are essential in the 21st century. The curriculum currently in use is the independent curriculum. The independent curriculum is a curriculum with diverse intracurricular learning where the content will be optimized so that learners have sufficient time to explore concepts and strengthen competencies. The competencies expected in this independent curriculum are 21st century learning competencies [6].

21st century learning in the era of globalization requires learners to have abilities that can help them face the demands of the times [7]. Critical thinking skills in physics learning are very important because they help learners analyze and understand physics concepts in depth [8]. With this ability, learners can solve problems, evaluate information, and apply physics knowledge in real situations, thus improving learner learning outcomes. In addition, critical thinking allows learners to not only memorize formulas and theories, but also understand the basic principles of physics. This helps them relate physics concepts to various phenomena that occur around them, making learning more relevant and meaningful.

The selection of appropriate teaching materials can support the smooth learning process in supporting 21st century skills. In facing the needs of the 21st century, teaching materials must be designed to train 21st century skills, such as critical thinking, which is included in the 4C skills. Ideal teaching materials are materials designed to help achieve learning objectives [9]. In addition, teaching materials serve to make it easier for teachers to deliver material. Teaching materials include various materials, tools, media, and information that are systematically arranged to develop the competencies needed by students. Learning will be more effective if teaching materials are tailored to the needs of students.

E-LWS is one type of teaching material that is used as an alternative for students. Sheets that refer to basic skills and contain instructions for performing tasks that learners do during learning learners must use digital electronics or the internet. E-LWS plays an important role in learning so that students can find themselves by following the learning process not just receiving material provided by the teacher. It is stated that E-LWS is for more effective learning, with the help of cell phones, computers, or laptops with images and animations along with videos [10]. This is appropriate in independent curriculum learning which is more centered on students to be more active than teachers, so that teachers can apply the use of E-LWS so that students are directly involved with the learning process. One model that is suitable for these problems is to use the STEM-based Problem Based Learning (PBL) learning model [11].

In line with this, efforts to improve the quality of education continue through various innovative learning models and approaches. Problems at the micro level of education include monotonous teaching models and approaches and lack of adequate facilities and infrastructure. In the 21st century, teachers need to implement various learning innovations to achieve educational goals [12]. Traditional teacher-centered and rote-based approaches are increasingly being abandoned, replaced by more interactive and participatory methods. Thus, the need for more effective and innovative learning approaches is becoming increasingly urgent to ensure that the education system is not only able to keep pace with the changing times, but can also equip learners with the necessary skills to succeed in the future. In this context, the STEM (Science, Technology, Engineering, and Mathmatics) approach is emerging as one of the recognized approaches that can enhance student engagement and help them develop skills relevant to the 21st century.

STEM-based learning requires a shift in the learning process model from the conventional teacher-centered model that relies on knowledge transfer towards a learner-centered learning model. The learning process relies on students' activeness, hands-on, and collaboration. STEM-based learning needs to be implemented in problem-based learning units. In the problem-based model learners are challenged critically, creatively and innovatively to solve real problems, which involves collaborative group (team) activities in learning.

The Problem Based Learning model has a primary focus on problems. Problem-based learning model often referred to as PBL model, is a learning model based on solving and investigating real problems [13]. In PBL learning activities, namely at the problem orientation stage, the teacher presents physics problems that are close to everyday life. Problem-based learning model always starts from a problem [14]. Problem based learning is a learning model by prioritizing a student centered approach that encourages students to conduct research activities, combining theory and practice, applying students' knowledge and skills to solve real problems. Problem based learning is a learning model that focuses on students by directing students to learn independently and be actively involved in group learning [15].

Based on the initial data obtained, it was found that teaching materials in the form of E-LWS were not yet available at SMA N 1 IV Koto with the standard teaching materials needed and expected in learning using the independent curriculum. Furthermore, it is also found that STEM-based E-LWS teaching materials with problem-

based learning models are not yet available which can be used to support students' critical thinking skills. Based on what has been described, it is necessary to make E-LWS based on the STEM approach with the PBL model on motion kinematics material to support students' critical thinking skills in order to assist teachers in meeting the lack of availability of STEM-based teaching materials with the PBL model.

Therefore, this study aims to develop and test the validity of STEM-based E-LWS products with PBL models as alternative teaching materials that are more innovative and effective in supporting students' critical thinking skills. With the presence of STEM-based E-LWS with PBL model, it is expected that teachers can more easily integrate digital media in learning, so that students have access to teaching materials that are more interesting, interactive, and able to improve their critical thinking skills. In addition, this research is also expected to be the first step in encouraging teachers to be more active in developing and using technology-based teaching materials, so that physics learning becomes more contextual, interesting, and in accordance with the demands of 21st century learning.

II. METHOD

This research is an R&D (*Research and Development*) *development* research with the 4D model [16]. The stages of this research are limited to three stages of development, namely the definition stage (define), the planning stage (design), and the development stage (develop). As for the disseminate stage, it was not carried out due to time constraints in its completion. This development research aims to produce STEM-based E-LWS with PBL model on motion kinematics material to support the critical thinking skills of valid SMA/MA students.

This research begins with the define stage which is used to determine and define the needs in the learning process. Furthermore, it enters the planning stage (design) which aims to design a physics E-LWS used in the learning process. In this stage, the design of learning media that best suits the conditions and characteristics of students is carried out. The next stage is the development stage (develop) consisting of feedback and expert trials. Expert validation is used to determine the feasibility of E-LWS that has been made and to get suggestions from experts.

The research was conducted at SMAN 1 IV Koto and the Physics Department of Padang State University (UNP). This research was conducted in the odd semester of the 2024/2025 academic year. The subjects of the development research used were 3 lecturers of Physics FMIPA UNP as validators to test the validity of the E-LWS that had been made. The object of this development research is STEM-based E-LWS with PBL model on motion kinematics material to support critical thinking skills of SMA/MA students.

The data used in this research is primary data. Primary data is data obtained directly from the research subject. Data obtained from validators in the form of a validity test questionnaire for STEM-based E-LWS with PBL Model on motion kinematics material to support critical thinking skills of SMA/MA students. The validation value is obtained by analyzing the questionnaire given and filled in by the validator. The validation assessment consists of several aspects which include material substance, visual communication display, E-LWS components, software utilization, and the use of the STEM approach with the PBL model to support the critical thinking skills of SMA/MA students in E-LWS.

The data obtained from the validation process was analyzed using Aiken's validity index to determine the suitability and validity of the E-LWS made. The validity analysis uses a likeart scale from 1 to 5 and after that it is processed using the Aiken formula to get the validity coefficient [17]. Ramus V Aiken is as follows:

$$V = \frac{\Sigma s}{n\,(c-1)} \tag{1}$$

The final calculation results determine whether the E-LWS meets the predetermined validity criteria. The validity criteria used can be seen from table 1 below

Table 1. Product Validity Criteria

No.	Value	Criteria
1	≥ 0,6	Valid
2	<0,6	Invalid

(Source: Ref[18])

III. RESULTS AND DISCUSSION

The purpose of this development research is to develop and produce STEM-based E-LWS with a valid PBL model to support students' critical thinking skills on motion kinematics material. The making of this E-LWS aims

to provide digital teaching materials that are interactive and in accordance with the needs of technology-based learning. The results obtained from starting from several stages to produce a valid E-LWS.

Define Stage

End Start Analysis

At this stage researchers conducted observations, interviews with teachers, distributing questionnaires to students at SMAN 1 IV Koto. based on the results of observations that have been made at SMAN 1 IV Koto, it is found that the critical thinking skills of students in physics learning are still relatively low. During the learning process students tend to be more passive and teacher centered learning. It can be seen from the acquisition of student value data in physics learning in Table 2.

Table 2. Average Critical Thinking Skills of Grade XI Students at SMAN 1 IV Koto

No.	Number of Students	Average score
1	22 people	48,82

Based on interviews that have been conducted with teachers, students are less interested in the implementation of physics learning because of their limited ability to solve calculation problems and consider physics lessons to be difficult. Furthermore, the existing problem is that students' literacy is low, making it difficult for students to develop 21st century skills, one of which is critical thinking skills. Based on the questionnaire sheet that has been distributed to students of class XI physics phase F, the obstacles felt by students are material that is difficult to understand. This is caused by many factors, one of which is the use of teaching materials and media that have not varied. Teaching materials used in the learning process only use printed books provided by the school library.

Learner Analysis

The analysis of students aims to see the characteristics of students at SMAN 1 IV Koto about the ability of students related to the making of STEM-based E-LWS with PBL model on motion kinematics material to support students' critical thinking skills. The questionnaire results obtained are that students tend to use various learning styles, such as audio, visual, audiovisual, and kinesthetic. Students want active physics learning and use learning media because students want fun learning.

Task Analysis

Task analysis is carried out to determine the material that will be presented to students. The learning outcomes (CP) of high school physics phase F subjects used in making STEM-based E-LWSs with PBL models on motion kinematics material to support the critical thinking skills of SMA / MA students can be seen in Table 3.

Table 3. Learning Outcome Elements

Learning Outcomes (CP)
By the end of Phase F, learners are able to understand the concepts of kinematics and dynamics, fluids, thermodynamics, waves, electricity and magnetism, and modern physics. These concepts enable learners to apply and develop their science inquiry skills.

Material Analysis

Material analysis is carried out to identify the material that will be presented in the LKPD developed. The first step in this analysis is to look at the material that is considered difficult for students to understand. The results of the analysis can be seen in Table 4.

Table 4. Materials Considered Difficult to Understand by Learners

No.	Aspects	Percentage (%)
1.	Magnitudes of Motion	45,45 %
2.	Regular Straight Motion	22,73 %
3.	Regularly Changing Straight Motion	59,10 %
4.	Vertical Motion	27,27 %
5.	Parabolic Motion	59,10 %
6.	Circular Motion	50 %

Learning Objectives

Analysis of learning objectives is an analysis that is the basis for constructing the E-LWS made. The learning objectives contained in the STEM-based E-LWS with PBL model on motion kinematics material to support

students' critical thinking skills include: 1) analyze the physical quantities of objects moving on a certain trajectory, along with their physical meaning and application, 2) process, analyze data and graphs of experimental results to investigate the characteristics of straight motion, parabolic motion and circular motion and their physical meaning.

Planning Stage (Design)

The design stage is carried out to make a design for making STEM-based E-LWS with PBL model on motion kinematics material to support students' critical thinking skills through three stages, namely media selection, format selection, and initial design.

Development Stage (Dessiminate)

Validation of STEM-based E-LWS products with PBL models on motion kinematics material to support students' critical thinking skills made was validated by three validators. The three validators are lecturers of the Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University. Validators provide an assessment of the E-LWS made by the author through filling in the instrument in the form of a validation questionnaire. The aspects assessed in the validity test are material substance, visual communication display, E-LWS components, software utilization, and the use of the STEM approach with the PBL model to support the critical thinking skills of SMA/MA students in E-LWS.

The first aspect of the validity instrument used based on the development of ICT-based teaching materials according to [19] is the substance of the material. This aspect consists of 4 assessment indicators consisting of 1) correctness, 2) material coverage, 3) currentness, and 4) readability. The results obtained can be seen through the graph displayed in Figure 1.

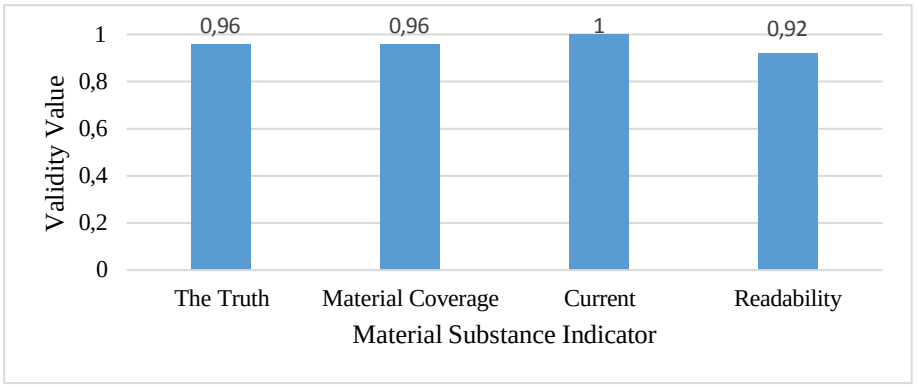

Fig. 1. Aspects of material substance

Based on the results obtained in Figure 1 from the material substance aspect, the validation results of this material substance range from 0.92 to 1. In the first indicator, namely the correctness of the material in the E-LWS, it shows a score of 0.96 which can be categorized as valid. The second indicator is the coverage of material in the E-LWS which shows a score of 0.96 which can be categorized as valid. The third indicator is the present in the E-LWS which shows a score of 1 which can be categorized as valid. Finally, the readability indicator has a score of 0.92 which can be categorized as valid. So that overall, the average validity score for this material substance aspect is 0.96 which is categorized as valid.

The second aspect of the validity instrument is the visual communication display. This aspect consists of 5 assessment indicators including 1) navigation, 2) font, 3) media, 4) color, and 5) layout. The results obtained can be seen through the graph shown in Figure 2.

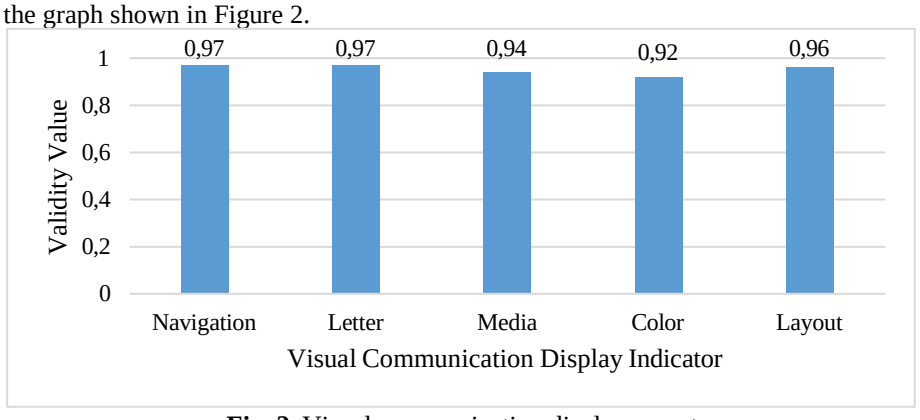

Fig. 2. Visual communication display aspect

Based on the results obtained in Figure 2 from the visual communication display aspect, the validation results of this visual communication display aspect range between 0.92 and 0.97. In the first indicator, namely from navigation, the assessment score is 0.97 which can be categorized as valid. Furthermore, the second indicator, namely the letter, obtained an assessment score of 0.97 which was categorized as valid. The third indicator is the media which shows a score of 0.94 with a valid category. The fourth indicator is color with a score of 0.92 which can be categorized as valid. The last indicator is the layout with an assessment score of 0.96 which can be categorized as valid. So that overall, the average score obtained in this aspect of visual communication display is 0.95 with a valid category.

The third aspect of the validity instrument is the E-LWS component. This aspect consists of several assessment indicators, namely 1) title, 2) learning instructions, 3) competencies achieved, 4) supporting information, 5) tasks and work steps, 6) assessment/evaluation, and 7) references. The validity results obtained can be seen through the graph presented in Figure 3.

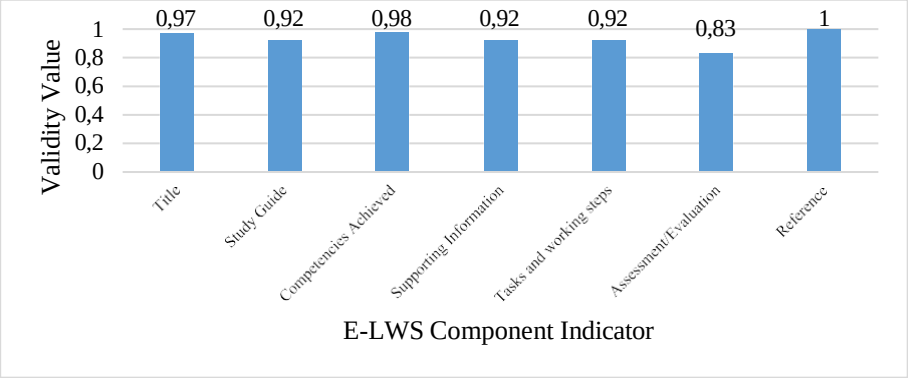

Fig. 3. Aspects of E-LWS components

Based on the results obtained from Figure 3 from the aspect of E-LWS components, the validation results in terms of E-LWS component aspects obtained scores from 0.83 to 1. The first assessment indicator is the title with a score of 0.97 which can be categorized as valid. The second indicator is the learning instructions with a score of 0.92 with a valid category. The third indicator is the competence achieved with a score of 0.98 which can be categorized as valid. The fourth indicator is supporting information with a score of 0.92 which is categorized as valid. The fifth indicator is tasks and work steps that have a score of 0.92 with a valid category. Furthermore, the sixth indicator is assessment / evaluation with a score of 0.83 which is categorized as valid. Finally, the indicator on the reference with the score obtained is 1 with the valid category. Overall, the average validity score for the E-LWS component is 0.95 with a valid category.

The fourth aspect of the validity instrument is software utilization. In this aspect, there are several assessment indicators, consisting of: 1) interactivity (feedback from the system to the user), 2) supporting software, and 3) originality. The validity results obtained in this aspect of software utilization can be seen through the graph presented in Figure 4.

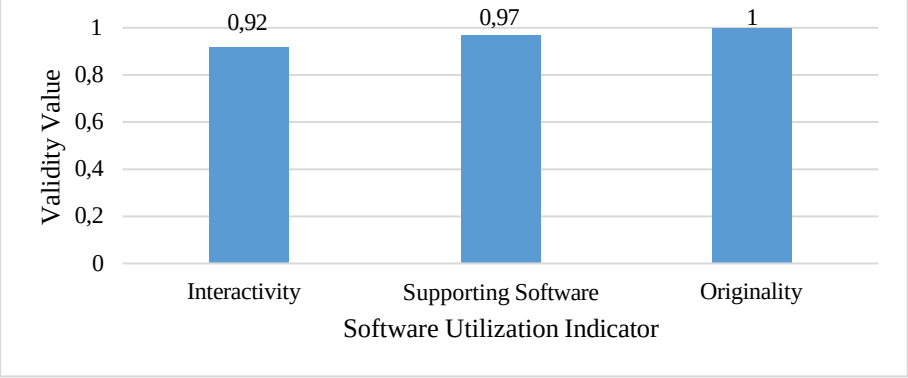

Fig. 4. Aspects of software utilization

Based on the results obtained from Figure 4 from the software utilization aspect, the validation results from the software utilization aspect obtained a score between 0.92 and 1. The first assessment indicator is interactivity (feedback from the system to the user) with a score of 0.92 which can be categorized as valid. The second indicator, namely supporting software, obtained a score of 0.97 with a valid category. Finally for the originality indicator

with a score of 1 which is categorized as valid. Overall for this aspect of software utilization has an average validity value of 0.96 with a valid category.

The fifth aspect of the validity instrument is the STEM approach contained in the E-LWS. This aspect has several assessment points in accordance with the STEM components, namely 1) science, 2) technology, 3) engineering, and 4) mathmatics. The results of the validity of the STEM approach component can be seen from the graph presented in Figure 5.

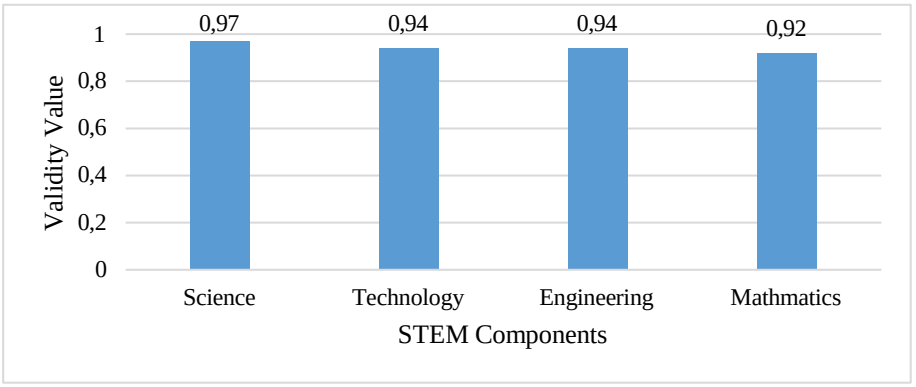

Fig. 5. STEM approach

Based on the results obtained from Figure 5 of the STEM approach, the validation results of the STEM approach obtained a score between 0.92 and 0.97. The first STEM component is science with a score of 0.97 which can be said to be valid. Next is technology with a score of 0.94 with a valid category. The next STEM component is engineering with a score of 0.94 with a valid category. The last STEM component is mathmatics with a score of 0.92 with a valid category. Furthermore, the overall average validity score based on the STEM approach aspect is 0.95 so that it can be categorized as valid.

The sixth aspect of the validity instrument is the problem-based learning model used in the E-LWS. In this aspect, there are 7 assessment items that are in accordance with the syntax of the problem-based learning model put forward by Arends. According to [20], there are 5 syntax indicators contained in this problem-based learning model. The validity results on the problem-based learning model component can be seen from the graph presented in Figure 5.

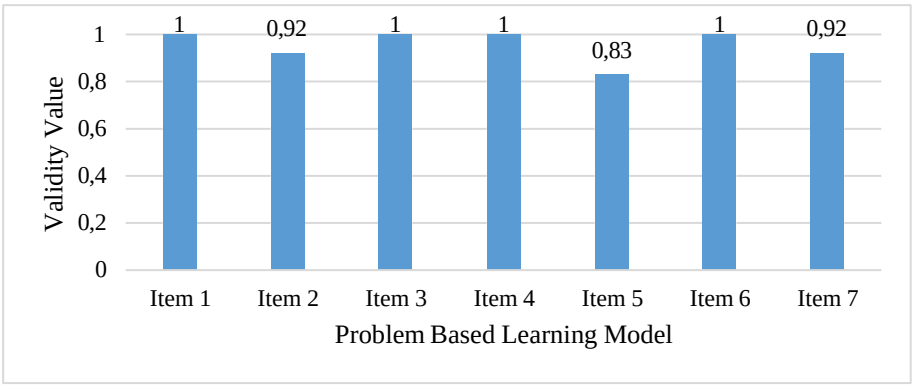

Fig. 6. Problem-based learning model

Based on the results obtained from Figure 6, the results of the validation analysis of the use of the problem-based learning model in E-LWS with a score between 0.83 and 1. For the first question item regarding the presence of syntax from the PBL model that helps students during the learning process obtained a score of 1 with a valid category. Furthermore, the second assessment item is related to the first syntax in the PBL model, namely problem orientation. The question item obtained a score of 0.92 with a valid category. The third assessment item is organizing students to learn with a score of 1 with a valid category. For the third question item related to the next PBL syntax. The next syntax is guiding the investigation with a validity score of 1 with a valid category. The fifth assessment item is the PBL syntax in the activity of developing and presenting work. This assessment item obtained a validity score of 0.83 with a valid category. The sixth assessment item is the PBL syntax in the activity of analyzing and evaluating the problem solving process in providing activity conclusions. This assessment item obtained a validity score of 1 with a valid category. Finally, the seventh assessment item is the PBL syntax in the activity of analyzing and evaluating the problem-solving process in providing evaluation/millennial questions.

This assessment item obtained a validity score of 0.92 with a valid category. Overall, the average validity score on the aspects of the problem-based learning model used is 0.95 so that it can be categorized as valid.

The last aspect is the critical thinking skills aspect contained in the E-LWS. In this aspect of critical thinking skills, there are several assessment indicators. These indicators consist of: 1) interpretation, 2) analysis, 3) explanation, 4) inference, 5) evaluation, and 6) self-regulation. The validity results on this aspect of critical thinking skills can be seen from the graph presented in Figure 7.

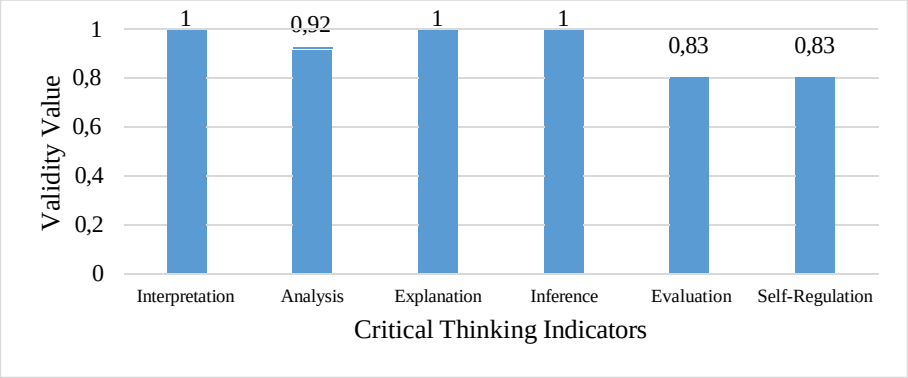

Fig. 7. Aspects of critical thinking skills

Based on the results obtained based on Figure 7, the results of the validation analysis of the critical thinking skills aspects contained in the E-LWS with a score between 0.83 and 1. The first assessment indicator is interpretation with a score of 1 which can be categorized as valid. The second indicator is analysis with a score of 0.92 with a valid category. The third indicator is explanation with the results of the validity score obtained 1 with the valid category. The next indicator is inference with a validity score of 1 with a valid category. The fifth indicator is evaluation with a score of 0.83 with a valid category. The last indicator is self-regulation with a validity score of 0.83 with a valid category. Overall, for this aspect of critical thinking skills, the average validity score is 0.93. This aspect of critical thinking skills can be said to be valid.

Overall to see the validity of the STEM-based E-LWS with PBL model, it can be concluded from the 7 aspects that have obtained the average score results. These aspects include: 1) material substance, 2) visual communication display, 3) E-LWS components, 4) software utilization, 5) STEM approach, 6) PBL model, and 7) critical thinking skills. Each of these aspects has an important role to ensure that the E-LWS made is able to increase students' knowledge, present electronic-based teaching materials that are attractive and effective to use. The assessment process aims to determine the validity and feasibility of E-LWS in supporting students' learning outcomes, especially in supporting critical thinking skills through the STEM approach with a problem-based learning model. High validity scores across these components indicate that the E-LWS is well structured. The following are the results of the average validity score for all components presented in graphical form as shown in Figure 8.

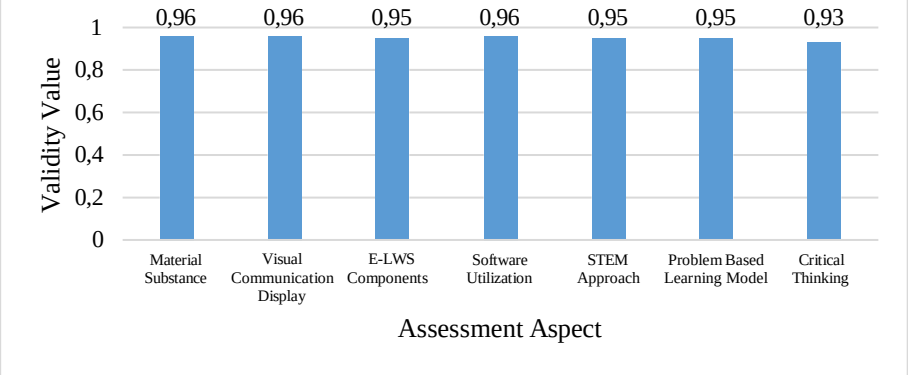

Fig. 8. Overall validity score of E-LWS assessment aspects

Based on Figure 8, it can be concluded that the STEM-based E-LWS with PBL model made to support students' critical thinking skills obtained a high validity value in each component. If explained in each aspect of the assessment, the material substance aspect with a result of 0.96 which is categorized as valid. The visual communication display aspect with a result of 0.96 which is categorized as valid. Aspects of E-LWS components with a result of 0.95 which is categorized as valid. The aspect of software utilization with a result of 0.96 which is categorized as valid. Aspects of the STEM approach with a result of 0.95 which is categorized as valid. Aspects

of the problem-based learning model with a result of 0.95 which is categorized as valid. Aspects of critical thinking skills with a result of 0.93 which is also categorized as valid.

The results of the validation of STEM-based E-LWS with Problem Based Learning (PBL) model made on the topic of motion kinematics show that the product has met the valid eligibility criteria from several aspects, namely 1) material substance, 2) visual communication display, 3) E-LWS components, 4) software utilization, 5) STEM approach, 6) PBL model, and 7) critical thinking skills. The assessment components used refer to the Directorate of Senior High School Development in 2010. The validation process was carried out in a structured manner by 3 experts from Physics lecturers at Padang State University. From the assessment results, this E-LWS gets an average score in the valid category which indicates that the product has met the criteria of validity requirements for learning activities. The validity reflects that the material is aligned with the curriculum, the steps are aligned with PBL objectives and the implementation of the instructional sequence facilitates active engagement, and the E-LWS is visually appealing and accessible to learners.

The first aspect assessed on this E-LWS is the substance of the material. The assessment results show a validity value categorized as "valid". This shows that the E-LWS has met the criteria of E-LWS in terms of the substance of the material. The second aspect is the visual communication display. The assessment results show a validity value categorized as "valid". In this case, the E-LWS has also shown good criteria in terms of visual communication display. The third aspect is learning design, in this case referring to the components of the E-LWS.

The fourth aspect is software utilization. The assessment results show a validity value categorized as "valid". This shows that the E-LWS has met the E-LWS criteria in terms of the software used. The next aspect is the STEM approach. . The assessment results show a validity value categorized as "valid". This shows that the E-LWS has met the E-LWS criteria from the aspect of the STEM approach contained in the E-LWS. The sixth aspect is the problem-based learning model. The assessment results show the validity value which is categorized as "valid". This shows that the E-LWS has met the E-LWS criteria from the aspect of the Problem Based Learning model contained in the E-LWS. The last is the aspect of critical thinking skills. The assessment results show a validity value that is categorized as "valid". This shows that the E-LWS has met the E-LWS criteria from the aspect of critical thinking skills contained in the E-LWS to assist students in achieving the desired competencies.

Based on the description of the research results, the results are obtained in the form of development products and data regarding the level of validity of STEM-based E-LWS with PBL model on kinematics material to support students' critical thinking skills. The results of this validity value are obtained after analyzing the data obtained using the Aiken index. If it meets the criteria then this E-LWS can be said to be valid. This research is relevant to previous research which states that a teaching material can be said to be valid if it has a score of $\geq 0{,}6$ [21].

The product in the form of E-LWS is equipped with supporting information, pictures, videos, experiments, and practice questions. STEM-based E-LWS with PBL model supports critical thinking skills of students. Through the STEM component and PBL syntax, students can find their own physics concepts and connect them to real-world events. The E-LWS presentation which is equipped with pictures and videos also helps students better understand the learning. The exercise questions provided also support students' critical thinking skills. In line with research conducted in previous researchers, the use of PBL-STEM can improve students' critical thinking skills [22]. Furthermore, there is also research stating that the application of STEM-based LKPD can improve students' critical thinking skills [23]. E-LWS is presented in online form so that teachers and students can access it via cellphone or laptop. The E-LWS made is also more interactive because it uses a liveworksheet platform. Relevant to previous research that the use of E-LWS using this liveworksheet makes students interested in learning as evidenced by the high interest of students in the learning process [24].

Validation of STEM-based E-LWS with PBL model on motion kinematics material to support students' critical thinking skills was carried out with three expert lecturers from the physics department of FMIPA UNP. The results of product validation obtained with an average acquisition of 0.95 with a valid category. A product can be said to be valid if the product is in accordance with the guiding structure. The results obtained illustrate that the E-LWS has fulfilled all the indicators contained in the assessment aspects in the validation of the E-LWS. From previous research which states that in addition to providing validation scores that have been carried out with experts, during the validation process lecturers or experts also provide improvements by providing suggestions and comments on the products made. So that the resulting product will be suitable for use [25].

With these results, it can be concluded that this E-LWS is not only theoretically and practically feasible, but also has great potential in supporting students' critical thinking skills. The integration of interactive digital media with the STEM approach and problem solving makes the learning experience more contextual, relevant, and fun. Therefore, the application of E-LWS like this is highly recommended not only for motion kinematics material, but can also be adapted to other physics materials and similar science lessons to support the transformation of learning that is responsive to the challenges of the 21st century.

IV. CONCLUSION

Based on the research that has been conducted, the results show that the STEM-based E-LWS with PBL model made to support students' critical thinking skills get a validity value of 0.95 which can be categorized as valid. The acquisition of this validation value indicates that the E-LWS made has met the eligibility standards set. The validity obtained is proven that the STEM-based E-LWS with PBL model meets various aspects of the assessment including material substance, visual communication display, E-LWS components, software utilization, STEM approach, PBL model, and critical thinking skills. With valid E-LWS criteria, this E-LWS can be used as one of the teaching materials in assisting the physics learning process, especially in motion kinematics material. Thus, this STEM-based E-LWS with PBL model is expected to be an innovative alternative in technology-based physics learning, which not only increases learning effectiveness but also supports 21st century skills needed by students, especially critical thinking skills.

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