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Integrating Palembang's Local Wisdom into a STEM-Based e-Module on Particle Dynamics to Foster Students' Creative Thinking Skills

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Abstract: This research aims to produce STEM-based particle motion dynamics e-modules in the context of local wisdom to train students' creative thinking skills. This research uses the 4D development model, namely the defining, planning, developing, and disseminating stages. This research involved 9 experts and 10 students in the limited trial stage and 20 students in the wider trial stage. The effectiveness test in this study involved 46 students of class XI from SMAN 2 Palembang. Creative thinking skills were measured using a creative thinking skills test which was then analyzed using the normalized N-Gain formula. The results of the expert appraisal validation showed that the content aspect scored 81% with very valid criteria, the media design aspect scored 74%, and the language aspect reached 76%, both of which were declared valid. At the broad trial stage, all aspects showed very practical results, with details of the ease of use aspect obtaining a percentage of 98%, the appearance and design aspects reached 95%, and the material presentation and benefit aspects each obtained a percentage of 96%. The effectiveness test showed that the average pretest and posttest scores were 27.96 and 79.45, with an overall N-Gain value of the creative thinking skills indicator of 0.7, which is in the high category. The results of this study conclude that the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom has been successfully developed and proven to have good validity, practicality, and effectiveness in training students' creative thinking skills, so it is feasible to use in physics learning in high schools.

Keywords: e-modules, physics, STEM, local wisdom, validity, practicality.

▪ INTRODUCTION

Physics is a study of matter and the energy contained within it that is closely related to natural events and phenomena. Learning physics also helps explain various events and phenomena that occur around us, making it a science that is very relevant to everyday life (Mulya et al., 2023; Ramadhanti, Kholilah, Fitriani, Rini, & Pratiwi, 2022; Sadiah, 2021; Sukarni & Sobri, 2023). Physics learning needs to emphasize the development of problem-solving, critical thinking, and creative thinking skills. These abilities are among the essential 21st century skills for students (Tientongdee, 2018). In the 21st century, the demand for critical thinking, problem solving, and creative skills is becoming increasingly prominent (Mitrevski, 2019).Mastering these skills allows students to analyze information in depth, generate innovative ideas, and apply physics concepts in real situations, so that they are ready to face complex problems in the modern world (Septeanawati & Yulianti, 2021).Therefore, physics learning plays an important role in 21st century skills.

The 21st century skills include Critical Thinking, Creativity, Communication, and Collaboration (Damayanti & Raharjo, 2020; Fahruddin, Liliawaty, & Siahaan, 2020; Kamilasari, Astutik, & Nuraini, 2019). 21st century skills are one of the important provisions that must be mastered by students to face modern life, especially in terms of creative thinking skills. Many studies report that the average score of students' creative thinking skills of 28.53% is classified as less creative. This indicates that students have

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not fully developed high-level thinking skills properly. Students tend to only be able to provide one solution in answering questions, which reflects that in terms of fluency, flexibility, and originality, their creative thinking skills still need to be improved (Reynawati & Purnomo, 2018; Rizal & Ambarita, 2018; Sirait, Sinaga, & Mulyono, 2018).

In learning, creativity will make students more active, confident, participate in discussions, solve problems, and take advantage of existing opportunities (Sativa, Wiyono, & Leni Marlina, 2022). Physics learning in Indonesia needs to be directed to develop creative thinking skills in students, in line with the learning objectives promoted by the Merdeka Curriculum (Kartika & Wahyuni, 2023; Marsini, 2023). The Merdeka Curriculum emphasizes the importance of developing creative thinking skills in physics learning. It aims to deepen students' understanding of physics principles and encourage them to develop new ideas and innovative solutions in solving problems (Mislah, Hayat, & Siswanto, 2024). To train creative thinking skills must be supported by the use of good teaching materials such as e-module teaching materials.

E-Modules are learning tools that are systematically structured to enable students to learn independently without the need for direct guidance from the teacher. The use of this module can also be adapted to students who have a higher learning speed (Triandini, Kosim, & Gunada, 2021). Currently, the development of e-modules in the learning process is packaged in the form of local wisdom to be close to students' lives. In learning that integrates local wisdom, students can understand physics concepts by observing how these concepts are realized in their daily lives and culture. This method helps students in connecting physics concepts with their application in the real world as well as their own cultural context (Asbanu, 2023; Pratomo, N., F. B., W., & Bahar, 2020). E-modules should include clearly structured approaches and principles.

One approach that is structured and clear is the STEM approach STEM (Thibaut et al., 2018). This approach is also in line with the principles of STEM education, which combines Science, Technology, Engineering, and Mathematics with real contexts, thus encouraging problem solving based on the surrounding environment (Periatna, Putri Mubarika, & Yaniawati, 2019; Suwardi, 2021). The STEM approach is one of the most relevant learning methods to 21st century education standards (Mulyasari & Sholikhah, 2021). In an age that continues to develop rapidly, the challenges faced by the younger generation are increasingly complex and not limited to one discipline. Therefore, STEM is an approach that can meet the needs of modern education.

Some research related to e-modules, STEM and local wisdom and those related to students' creative thinking skills have been carried out by producing valid, practical, and effective e-modules (Dani, Jufrida, Basuki, & Aprily, 2022; Khairunnisa, Sugiarti, & Lia, 2023; M. Wati, Apriani, Misbah, Miriam, & Mahtari, 2021). However, no research has been found that develops STEM-based e-modules in the context of Palembang local wisdom that refers to the independent curriculum to train students' creative thinking skills. Based on the needs analysis that has been obtained, 94.4% of students stated that it is necessary to develop a STEM-based physics e-module in the context of Palembang local wisdom. Based on this description, it is necessary to develop STEM-based physics e-modules in the context of Palembang local wisdom. The purpose of this research is to produce STEM-based physics e-modules in the context of Palembang local wisdom that are valid, practical and effective.

▪ METHOD

The research was conducted from June to December 2024 in the odd semester at SMA Negeri 2 Palembang, involving 9 experts and 10 students at the limited trial stage and 20 students at the broad trial stage. Subjects in the e-module trial were selected grade XI students because the material related to particle motion dynamics was being studied. This research used the 4D development method which includes define, design, develop, and disseminate (Sari, Abdurrahman, & Lengkana, 2022; Utami & Prodjosantoso, 2024; Vanzal & Dwiningsih, 2023). This 4D development model was chosen because it has systematic and structured stages, and this model is product-oriented, especially in effective and quality teaching materials (Dewy, Isnaini, Simamora, Silitinga, & Astrid, 2023; Riani Johan, Iriani, & Maulana, 2023). In addition, the advantages of the 4D model have a simple and systematic procedure, in accordance with the research steps to be carried out, and in its development involves expert judgment so that before the developed trial has been revised based on the assessment, suggestions, and input of experts (Afridiani & Faridah, 2021; Munir, Pratikto, & Rahayu, 2024). Therefore, the 4D model not only supports systematic development but also produces products that are contextual and have a positive impact on learning (Komisia, Tukan, & Uron Leba, 2021).

The research flow of this 4D development model consists of four stages, which include the define stage. During this stage, several activities will be carried out, including the initial-final analysis, student analysis, concept analysis, task analysis, and formulation of learning objectives (Darmawati, Raharjo, & Azizah, 2023). The contribution of this stage is to ensure that the e-module is aligned with the needs of students and is relevant to the context of local wisdom, serving as a foundation for content validity. At this stage of the design process, the focus is on the development of the e-module framework, as well as the preparation of instruments, selection of media and format, and initial design (Salsabella, Iriani, & Saleh, 2023), The contribution at this stage is that a good design will support the practicality aspect of the e-module, making it easy to use by students and teachers. At the develop stage, it is divided into two, namely first, expert validation testing to assess product feasibility, and second development testing to evaluate product practicality consisting of limited trials and broad trials (Salsabella et al., 2023). The contribution of this stage is that through validation and trials, the e-module can be adjusted until it meets the expected standards of validity and practicality. At the Disseminate stage, an effectiveness test is conducted to assess changes in creative thinking skills before and after the implementation of the e-module (Utari, Gunada, Makhrus, & Kosim, 2023), the contribution at this stage ensures that the e The e-module is implemented on a broader scale after undergoing limited and extensive trial stages, and the effectiveness of the e-module in enhancing creative thinking skills is demonstrated by the results of the implementation.

Data collection employed non-test instruments, namely expert validation sheets and student response questionnaires, as well as one type of creative thinking skills instrument. According to the National Education Standards, the expert validation instrument is adjusted to the textbook standard and validated by the team (Wulanningtyas Eva, Arfi, & Ramadhan Fajar, 2020). Expert validation at the expert appraisal stage includes 3, namely content aspects, media design aspects and language aspects. The student response questionnaire includes 4, namely aspects of ease of use, appearance and design aspects, material presentation aspects and benefits aspects (Riski, Bentri, Eldarni, & Yusri, 2023).

Student response questionnaires were used in the limited trial and broad trial stages. The results of expert validation and student response questionnaires were then analyzed to determine the validity and practicality of the e-modules developed. The development of e-modules follows a systematic process, beginning with the validation and development test stages. The development process commences with the creation of learning products, which are then validated by experts. In the event that a product does not pass validation, it is revised and returned to the development stage. If it passes, the product advances to the development test. The product then enters the practical test stage, which consists of two stages: a broad trial and a limited trial. Table 1 below presents a comprehensive overview of the instruments utilized in expert validation.

Table 1. Expert validation instrument grid

No	Aspects	Indicator
1	Content	Suitability of e-module material with curriculum areas
		Material coverage
		Correspondence with the elements of STEM.
		The suitability of the material with the context of local wisdom
		Suitability of e-modules with creative thinking skills
2	Media Design	Accuracy of Presentation
		Presentation of Learning
		E-module display
3	Language	Communicative
		Suitability with students' development.
		Compliance with the rules of proper and correct Indonesian language

Based on Table 1, an example of a statement used in the validation sheet, for example in the content aspect with an indicator of the suitability of the e-module material with the curriculum field, namely "The material in the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom is in accordance with the learning objectives of phase F in the Merdeka Curriculum" This statement provides a concrete description of how the validation instrument assesses the alignment of the e-module material with the applicable curriculum standards. Experts who validate e-modules have qualifications according to their fields. Material experts with a background in physics, especially STEM-based physics concepts integrated with local wisdom, ensure the e-module content is accurate, curriculum compliant, and relevant to the learning objectives. Media design experts who are experienced in digital, instructional, visual, and multimedia design, aim to create e-modules that are attractive, interactive, and user-friendly. Linguists ensure the use of language in the e-module is clear, communicative, and appropriate for students' level of understanding. The involvement of these experts covers content, design, and language to achieve a high standard of validity of the e-module (Afridiani & Faridah, 2021).

The data analysis technique uses product feasibility analysis obtained from the average results of experts, while the analysis of student responses refers to the Gutman scale (Sugiyono, 2013). The expert validation results are based on the Gutman scale. The data analysis technique employs product feasibility analysis derived from the mean outcomes of experts, while the analysis of student responses adheres to the Gutman scale (Sugiyono, 2013).The expert validation results are based on the Gutman scale. The

assessment criteria employ a Guttman scale, comprising two criteria: "Yes" with a weight of 1 and "No" with a weight of 0. As posited by Akbar, (2017) in (Meliana, Herlina, Suripah, & Dahlia, 2022), the validation score is calculated by dividing the total empirical score obtained from the ith validator by the maximum total score. This value is then multiplied by 100% to obtain the results of each validator.Subsequently, the validation results from each validator are calculated, and the next step is to determine the combined validity of all validators. This combined validity is calculated by summing the percentage of validation process scores from each validator and dividing it by the number of validators.The validation score that has been calculated in percentage form is interpreted into the validity criteria.

The validation results from each validator were analyzed and calculated using the formula, as stated by Akbar, (2017) in (Meliana et al., 2022). In this study, the validity consists of three aspects, with each aspect having three validators. This corresponds to the statement by Akbar, (2017) that one aspect is represented by three validators, so that the Akbar formula is used (2017). The data is then grouped based on the validity criteria established by Akbar, (2017), which are divided into five categories. Products with a validity percentage between 81.00% and 100.00% are categorized as "very valid," indicating that the product can be used without improvement. Products with a validity percentage between 61.00% and 80.00% are considered "valid," signifying that most of the criteria have been met but necessitate minor improvements. Products with a validity percentage ranging from 41.00% to 60.00% are classified as “moderately valid”, signifying the necessity for substantial revisions, as only approximately half of the criteria are met.Products with a validity percentage between 21.00% and 40.00% are designated as “not valid”, indicating a complete failure to meet the established criteria. Finally, a validity percentage between 0.00% and 20.00% is classified as "Very Invalid," indicating that the product fails to meet nearly all criteria and necessitates a comprehensive overhaul or replacement.

Table 2. Grid of student response questionnaire instrument

No	Aspects	Indicator
1	Ease of Use	Ease of access
		flexibility
		Navigation
		Instructions for use
2	Display and Design	Consistency of video, image/photo display
		Illustrations that support the material
3	Presentation of Material	Clarity and Ease of Understanding the material
		Language used in the e-module
4	Benefits	The usefulness of the e-modules used
		Suitability of creative thinking skills

Table 2 provides a clearer picture of the instrument lattice used in the student response questionnaire, with examples of statements used in the questionnaire, such as the following on the aspect of ease of use with indicators of usage: "The instructions on the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom are clear and understandable" The Guttman scale was used in the student response questionnaire to assess the practicality of the e-module product. The Guttman

scale, with its binary structure, offers a solution to the challenges posed by traditional rating scales. By design, the Guttman scale assigns a score of 1 to the "Yes" response and a score of 0 to the "No" response, thereby ensuring the minimization of bias and the maximization of objectivity in the assessment process (Asih & Muslim, 2023).

The results of the student response questionnaire used in the limited trial and broad trial stages of students were analyzed with percentage data from the Guttman scale, where P is the percentage of student answers, F is the number of respondents' answers and N is the respondent's score. Suggestions from experts or students were analyzed using content analysis seen from the results of comments or suggestions from the content. Then the percentage results are grouped based on the practicality criteria according to (Kaukaba, Nora, Fattikasari, Rizqiyah, & Lutfi, 2022) which are divided into five categories, namely the percentage between 81% and 100% is considered very practical. If the percentage is in the range of 61% to 80%, then the instrument is considered practical. Furthermore, the percentage between 41% to 60% is in the moderately practical category. The percentage criteria between 21% to 40% are considered not practical. Meanwhile, the percentage between 0% to 20% is classified as not very pratical. This criterion is used because the assessment of practicality is measurable and objective, so it is suitable for assessing practicality and then this criterion uses calculations using a guttman scale so that it is in accordance with this study. The data provided by validators or respondents is kept confidential which is only used in this study.

The results of the creative thinking skills test, both before (pre-test) and after (post-test), were analyzed by applying the normalized gain formula, then interpreted based on the classification into three categories (Maryani, Putri, & Supriadi, 2022), consisting of if the N-gain value is 0.7 or more, then the improvement is categorized as high. If the N-gain value is in the range of 0.3 to less than 0.7, then the improvement is categorized as moderate. Meanwhile, if the N-gain value is less than 0.3, then the improvement is categorized as low.

▪ RESULT AND DISSCUSSION

The results of this study are STEM-based particle motion dynamics e-modules in the context of Palembang local wisdom which aim to determine the results of validity and practicality. The e-module was developed in accordance with the 4D development procedure with the results of e-module development from each stage as follows.

Define

This stage contains a beginning-end analysis, student analysis, concept analysis, task analysis and formulation of learning objectives. The results at this defining stage show that the Merdeka Curriculum supports student-centered learning with flexibility for teachers to adjust it. 21st century learning is very important for students to master, so that students can solve problems and innovate, but learning tools in schools often lack support, making students tend to memorize without understanding the application, especially in STEM-based physics. Because of this situation, it is necessary to present an e-module on STEM-based physics learning that is associated with Palembang local wisdom. The STEM approach associated with this local wisdom creates learning will certainly be easier for students to understand, if used in e-modules, it will be very important and therefore very suitable to be applied in learning activities (Suwarma & Kumano, 2019). As many as 65.3% of students stated that they more often use printed and electronic teaching

materials, this is in line with previous research that teaching materials are commonly used in the form of modules, both in printed and electronic form (Riyasni, Yani, Sari, & Zulhendra, 2023). As many as 70.8% of students find it easier to understand the material when it is related to the context of everyday life and as many as 94.4% of students think that it is necessary to develop STEM-based physics e-modules with the context of Palembang local wisdom. This finding is in line with previous research that emphasizes the importance of developing STEM-based physics e-modules in the context of local wisdom (Fitria et al., 2023; Syarah Syahiddah, Dwi Aristya Putra, & Supriadi, 2021). The selected physics concept is the material of particle motion dynamics class XI, the material is mapped through concept analysis, resulting in several submaterials arranged in the e-module and the formulation of learning objectives.

Design

The results at this design stage are designing STEM-based particle motion dynamics e-modules in the context of Palembang local wisdom in accordance with the STEM approach, first preparing instruments based on product needs and then designing a learning process activity plan carried out for 3 meetings, designing e-module prototypes will be made starting from selecting the application that we will use in this study using the articulate stroyline application, selecting the articulate storyline application because it has many interesting features and can be directly published online and makes it more accessible and effective (Hadza, Sesrita, & Suherman, 2020; Ramadhan Mas, Algadig Furqob, & Didimyati, 2023). In this stage we also compile the structure of the e-module which includes cover, preface, table of contents, instructions, introduction, e-module description, learning activities, evaluation questions along with answer keys, summary, glossary, bibliography (Ayani, Sundari, & Sari, 2023). Then produce an initial prototype in the form of an e-module, which is presented in Figure 1.

Figure 1. E-Module initial prototype results

Develop

The results of data analysis obtained at the expert validation stage on 3 aspects of validation can be seen in Table 3.

Table 3. Results of e-module validity testing on expert validation tests

Aspects	Validator	Emp Score	Max Score	Percentage Value Overall validity	Criteria
Content	Validator 1	20	22	81%	Very Valid
	Validator 2	14	22		
	Validator 3	20	22		
Media Design	Validator 1	16	21	74%	Valid
	Validator 2	14	21		
	Validator 3	17	21		
Language	Validator 1	7	10	76%	Valid
	Validator 2	7	10		
	Validator 3	9	10		

The percentage of expert validation results is classified based on expert criteria according to Akbar, (2017). Based on the results at the expert appraisal stage or expert validation test, the percentage in the content aspect is 81% with very valid criteria, this is in line with previous research which states that the overall percentage of validity in e-modules reaches very valid criteria (Amalia, Pasani, & Yulinda, 2021; Chandra, Haris, & Yulita, 2021; Santoso & Suyono, 2021). The content aspect gets a high validity score compared to other aspects because this aspect is closely related to the relevance and suitability of learning materials to learning objectives, curriculum, and learner needs. The content presented may be in accordance with curriculum standards and support the achievement of basic competencies. If the material in the e-module is in accordance with the curriculum standards and supports the achievement of the expected competencies, then the content validity will be rated high (Syarah Syahiddah et al., 2021). In addition, the integration of local wisdom in e-modules can increase the relevance and connectedness of the material to the learners' environment, which contributes to the high content validity score.

The percentage of media design with a value of 74% with valid criteria, according to related research, STEM-based e-modules in the context of local wisdom need to be evaluated from various points of view, including design (Aulyana & Fauzi, 2023). The language aspect received a percentage of 76% with valid criteria. In contrast to the content aspect which is at the very valid criteria, the media design aspect and the language aspect are only at the valid criteria, this is because there are several improvement notes given by the validator related to the media design aspect and the language aspect. Therefore, although these two aspects have been declared valid, some revisions are still needed to achieve a higher level of validity. This is supported by previous Latif, Yusuf, & Dama (2022), D. K. Wati, Saragih, & Murni (2022) in several development studies, there are products that are considered valid but have not reached the very valid category. This is usually caused by suggestions and input from validators that still require further revision. The examples of comments or suggestions on the expert validation test are “in the engineering and technology section, pay more attention to what is still wrong and not visible”, “note that there are still sentences that are not in accordance with PEUBI” and “fix the page numbers and font types on the product”. Overall, this STEM-based particle motion dynamics e-module in the context of local wisdom of Palembang is valid and feasible to be tested. These results are in line with previous research reported by Melinia,

Ismet, & Yusup (2024), Novitasari, Connie, & Risdianto (2022), Qohar, Susiswo, Nasution, & Adem (2019), Wulandari & Radia (2021) showing that if a learning product that has been validated by experts and meets valid criteria can proceed to the trial stage. Figure 2 below shows a comparison of the results of expert validation on each aspect.

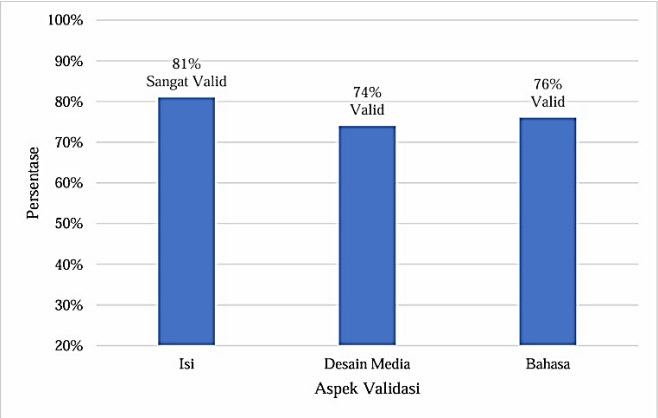

Figure 2. Comparison of expert validation results on each aspect

The practicality test was conducted using a student response questionnaire. The practicality of teaching materials aims to assess their effectiveness in supporting student learning activities (Kalkman, 2012; Misbah, Sasmita, Dinata, Deta, & Muhammad, 2021). To get practicality, two trials were conducted, namely a limited trial and a broad trial. Students will be given the opportunity to use or access the STEM-based particle motion dynamics e-module that raises the context of Palembang local wisdom. Students are asked to provide an assessment and comments related to the e-module. The results of the assessment at the limited trial stage are shown in Table 4 as follows.

Table 4. Results of e-module practicality testing on limited trial

Aspects	Percentage	Criteria
Ease of Usability	98%	Very Practical
Look and Design	96%	Very Practical
Presentation of Material	96%	Very Practical
Benefits	90%	Very Practical

Based on Table 4, the results of the assessment at the limited trial stage obtained results in the aspect of ease of use of 98% with very practical criteria, in the aspect and design of 96% with very practical criteria, then the presentation of material 96% also with very practical criteria, and in the aspect of benefits of 90% with very practical criteria. So for the limited trial as a whole, the e-module was declared very practical. Ten students were also entitled to input and suggestions related to the product developed. Input and suggestions from students are used as consideration in revising the products developed (R. Saputra, Thalia, & Gustiningsi, 2020; Syuhendri, Sania, & Akhsan, 2021; Widyastuti & Susiana, 2019; Wiyono, 2016; Wiyono, Madang, et al., 2024). E-Modules that have been declared very practical at the limited trial stage will then proceed to the broad trial stage. The results at the broad trial stage are shown in Table 5 as follows.

Table 5. Results of e-module practicality testing on a broad trial

Aspects	Percentage	Criteria
Ease of Usability	98%	Very Practical
Look and Design	95%	Very Practical
Presentation of Material	96%	Very Practical
Benefits	96%	Very Practical

Based on the results of the data for the broad trial in Table 5, it shows that the ease of use aspect gets a percentage of 98%, the appearance and design aspect is 95%, the material presentation aspect is 96% and the benefit aspect is 96%. So overall e-modules in all aspects get very practical criteria. These results are in line with previous research that this can help identify areas that need improvement and evaluate the effectiveness of educational interventions, such as the application of e-modules (Bukit, Perangin-angin, & Murad, 2022). The ease of use aspect shows that e-modules are used effectively. Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich (2017) emphasized that easy-to-use appearance and design increase user comfort, and further Richard E. Mayer (2020) that the presentation of well-structured material increases understanding. On the other hand, the benefits of the device show a real contribution to learning, which supports the results (Bower, 2019). These results indicate that the device is designed to meet user needs and can be widely used. So overall, the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom at this stage is very valid and very practical.

There was overall no significant difference in the aspects of "Ease of Use" and "Presentation of Material." but there was a significant increase in the benefit aspect by (6%) and for appearance and design there was a slight decrease (1%). The ease of use aspect received the highest practicality score (98%) in both the limited and broad trials. This shows that the developed e-module is very easy to access and use by students. This high score reflects that the e-module has a user-friendly user interface with intuitive navigation, so students do not experience difficulties in accessing learning materials. This is supported by previous research reported by (Manggala et al., 2024) showing that e-modules bring a significant positive impact in bridging the learning gap through innovative and more interactive approaches.

Based on the results of the limited trial and the broad trial, it is known that overall from the two trials the e-modules developed are on very practical criteria. These results are in line with previous research reported by Andrianto, (2024) showing that the e-module developed obtained 89.47% with very practical criteria, which means that the e-module is very feasible to use in the learning process. Previous research conducted by Prihastuti, Sukaesih, & Sekaran, (2024) also showed responses from students obtained a percentage of 96.43% and 90% with very practical criteria. This high practicality indicates that e-modules are easy to use, in accordance with student needs, and effective in supporting the learning process. The implementation of STEM in learning also shows positive effects, such as supporting the development of creative thinking skills and practicing students' interest in learning (Yasifa, Hasibuan, Siregar, Zakiyah, & Anas, 2023). So overall, the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom at this stage is very valid and very practical. Figure 3 below shows the comparison of the results of the limited trial and the broad trial.

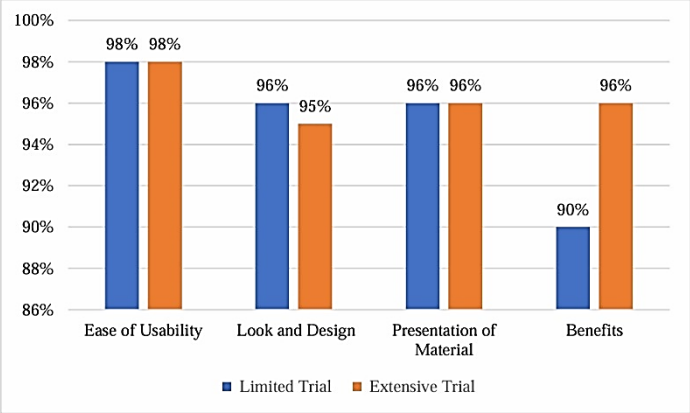

Figure 3. Comparison of limited trial and extended trial results on each aspect

Disseminate

At this stage of dissemination, testing will be done by conducting pre-tests and post-tests with 46 students in class XI.1 SMA Negeri 2 Palembang. This test aims to determine the extent to which the e-module is able to train students' creative thinking skills (Lutfiah, Suharti, & Asy'ari, 2021; Pertiwi Sekar, Abdurrahman, & Rosidin, 2017). The mean scores of the pretest and posttest are presented in Table 5.

Table 5. Pretest and posttest results

No	Results	Average	N-Gain
1	*Pretest*	27.96	0.7
2	*Posttest*	79.45	

Based on Table 5 above in the pretest, the average score obtained by students is 27,96. While in the posttest the average value of students is 79,45. This shows that there is an increase in the value of students before and after using the developed e-module. it can be seen that the average posttest value is higher than the average pretest value, namely with a difference of 51,49. From the table above, it can also be concluded that the average interpretation of students in class XI.1 SMA Negeri 2 Palembang is High with an average n-gain value of 0,7.

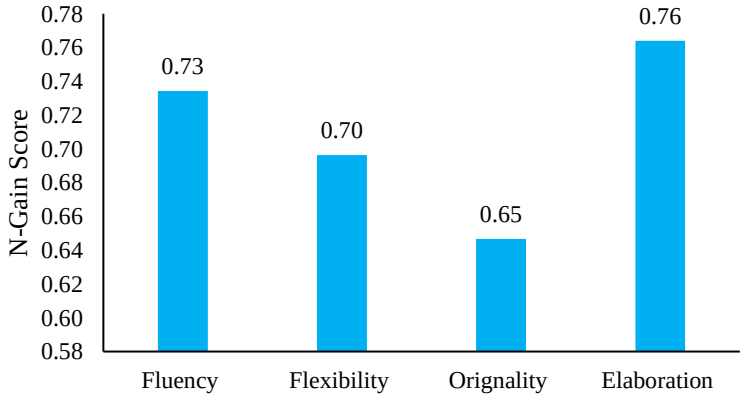

Figure 4. N-gain for each indicator of creative thinking skills

As illustrated in Figure 4, the fluency, flexibility, and elaboration indicators exhibit an average n-gain of 0.7, indicating a high level of effectiveness. In contrast, the originality indicator demonstrates an average n-gain of 0.65, placing it in the medium category. The data obtained thus far indicates that the implementation of the STEM-based particle motion dynamics e-module within the context of Palembang local wisdom is an effective medium for enhancing the creative thinking skills of high school students. This finding aligns with the conclusions drawn from prior research (Antika & Nawawi, 2017; Handayani & Koeswanti, 2021; Panjaitan, 2023) which attests to the efficacy of STEM-based particle motion dynamics e-modules in the context of Palembang local wisdom in fostering creative thinking skills among high school students.

Based on the stages that have been carried out, the results obtained that the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom to train high school students' creative thinking skills are declared valid, practical and effective. This finding is in line with previous research that produces similar products, namely physics e-modules based on local wisdom to improve creative thinking skills that are valid, and practical (Fitonia, Wiyono, & Sriyanti, 2024), STEM-based e-modules to improve students' creative thinking skills that are very valid, very practical and effective (Wulansari, Irdawati, Razak, Chatri, & Fajrina, 2023), STEM physics module integrated with local wisdom "Beduk" to improve creative thinking skills of junior high school students which is valid, and practical (Almuharomah, Mayasari, & Kurniadi, 2019a), physics module based on Islam-science integration on straight motion material to improve valid, practical and effective learning outcomes (Husna, Hasan, Mustafa, Syukri, & Yusrizal, 2020), physics e-modules assisted by augmented reality based on local wisdom Becak to improve mathematical communication, development of valid, practical and effective momentum and impulse teaching materials (Pahlawan, Ismet, & Syarifuddin, 2021) and effective critical thinking skills (Poppy Sari & Kuswanto, 2020), STEM-based electrical modules of optical devices using the Flip PDF Professional Application which are valid and practical (Rizaldi, Sudirman, Saparini, & Pasaribu, 2022).

The results of expert validation and student trial results provide a comprehensive picture of the quality of e-modules that are not only theoretically valid or according to experts but practical and effective in their use during the learning process. The alignment between expert assessments and student responses can vary depending on the aspects being evaluated (Ramli, Sakti, Basri, Idamyanti, & Yusdarina, 2024). This alignment strengthens the quality of the e-module as a learning media that is relevant, contextual, and able to support the understanding of STEM-based physics concepts with Palembang local wisdom values. High alignment in key aspects such as content quality and learner engagement indicates that the e-modules have successfully met expert standards and student needs (Ombili et al., 2023). The e-modules developed in this study were designed not only to provide understanding of physics concepts but also to support the development of students' skills in accordance with the demands of 21st century learning, particularly for creative thinking skills. The e-module developed not only presents interactive learning materials, but is also equipped with discussion rooms and tasks to encourage creativity (Jafnihirda, Suparmi, Ambiyar, Rizal, & Pratiwi, 2023; Mutia et al., 2025). In addition, this e-module is designed with creative thinking indicators to hone students' skills in finding innovative solutions.

The STEM approach applied in this module is also integrated with local wisdom, so that learning becomes more contextual, relevant, and close to students' daily lives. This is in line with previous research which states that students can improve their creative thinking skills with e-modules made with the STEM approach and integration of local wisdom because they are relevant and close to students (Almuharomah, Mayasari, & Kurniadi, 2019b; Rofikoh, Supeno, & Farisi Imam, 2020). A concrete example is through tasks that encourage students to provide new ideas in integrating modern technology with local wisdom, for example in the context of the Palembang pyramid house and gravity. The development of this e-module is relevant to constructivism learning theory as evidenced by the existence of STEM-based e-modules. Constructivism theory emphasizes that learning is an active process where students construct their own understanding based on previous experiences and knowledge (Julia, Fitriani, & Setiawan, 2024; Suparlan, 2019). In the STEM context, students engage in activities that allow them to explore and discover new concepts through direct experience (Sujarwanto, 2023).

The STEM-based particle motion dynamics e-module in the context of Palembang's local wisdom specifically integrates Palembang's local wisdom, such as the thimble boat race on Newton's Law material, the pelimaran technique on the concept of friction force, songket weaving on the topic of momentum and impulse, and the Palembang Limas House on the concept of gravity and normal force. This integration makes learning more meaningful and relevant, because students can understand that physics does not only apply in examples that are far from their lives, but also present in their daily lives (Aulia, Pratiwi, & Kuswanto, 2024). On the concept of frictional force, the ejection technique provides a concrete example of how friction plays a role in the process of making traditional Palembang cloth. This helps students link physics theory with real cultural processes (Fatmi, Fitriani, & Fauzan, 2024; Pardede, Sitorus, & Harmuda, 2024; I. G. P. E. Saputra, 2024).

The context of Palembang's local wisdom is very relevant in students' lives. Integrating local wisdom and STEM approaches into learning is an effective method to train students' creativity. Research supports this integration as it combines traditional knowledge with modern scientific principles, creating a culturally relevant learning environment and practicing creative and critical thinking skills (Babalola & Keku, 2024; Noorhapizah, Agusta, & Pratiwi, 2020; Sumarni & Kadarwati, 2020; Wiyono, Ismet, et al., 2024). Many things can affect students' creative thinking skills, such as directly observing or experiencing events that occur in the environment around them. The development of STEM-based e-modules that integrate Palembang local wisdom to train students' creative thinking skills still has opportunities to be further improved to make it more relevant and effective in supporting learning. One aspect that needs to be considered is the improvement of media design such as visual design and navigation features of e-modules, then one aspect that needs to be considered is the improvement of interactive content in e-modules (Sulastri, Irvani, & Warliani, 2024). Providing interactive simulations and virtual laboratories can be a concrete step to help students understand physics concepts through hands-on experience (Arifin, Prastowo, & Harijanto, 2022). Then strengthened by adding adaptive quizzes equipped with automatic feedback, this e-module also has the potential to be adapted in different learning contexts. Adjusting the content to suit local wisdom from other regions will make this e-module relevant for students in different regions. That way, students not only learn physics concepts but also

broaden their horizons about the application of science in various local cultures as well as other 21st century skills.

▪ CONCLUSION

Based on the research that has been carried out, it can be concluded that the STEM-based particle motion dynamics e-module in the context of Palembang local wisdom has been successfully developed and declared very valid in the content aspect with a percentage of 81%, in the language aspect with a percentage of 76% valid and the media design aspect gets 74% valid. The developed e-module also falls into the very practical category both in the aspect of ease of use 98%, the appearance and design aspects with a percentage of 95%, the presentation of material 96% and the benefit aspect gets a percentage of 96%. And particle motion dynamics e-modules are effective in training creative thinking skills with an N-Gain of 0.71 with a high category. There are advantages in using e-modules. E-modules have the advantage that e-modules can be accessed at any time and can be accessed independently and also this e-module has features that can facilitate students in using it. This e-module also has the disadvantage that it can only be accessed online. It is hoped that the developed e-module can be one of the innovative learning resource options for high school teachers and students to help students gain knowledge, especially in practicing skills that are relevant to the modern world, especially creative skills. In addition, future research is recommended to develop physics e-modules with other STEM-based physics materials in the context of local wisdom of other regions in order to train 21st century skills.

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