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Integration of Augmented Reality and the Treffinger Model in a Physics E-Module to Facilitate Creative Thinking of MA/SMA Students

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ABSTRACT

Students' creative thinking ability in physics learning remains relatively low because instruction is dominated by printed teaching materials that are insufficiently contextual and by conventional teaching models that give students limited opportunities to develop ideas, flexibility, and originality. This study aims to describe the development process and the quality of a physics electronic module (e-module) based on the Treffinger model and enriched with augmented reality (AR) on the topic of Work and Energy, in terms of validity and practicality. The study used a Research and Development (R&D) approach with the Plomp development model, which consists of preliminary research, prototype development, and assessment. The product was validated by three expert validators covering the construction, content, and language aspects, and was tested on one physics teacher and 20 Grade X Phase E students at MAN 2 Agam. Data were collected through Likert-scale questionnaires. The results show that the e-module achieved an average validity score of 86%, categorized as very valid, and an average practicality score of 89.5%, categorized as very practical. The teacher and student assessments were 97% and 82.3%, respectively. Analysis of the creative thinking indicators revealed that elaboration was dominant (50%), followed by originality (21%), while fluency and flexibility each accounted for 14%. These findings indicate that integrating Treffinger and AR produces feasible teaching materials that support creative thinking. Further research is recommended to test effectiveness through an experimental design.

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INTRODUCTION

Creative thinking is an essential 21st-century competency that enables individuals to generate new, original, and applicable ideas from the knowledge and experience they already possess (Utomo Aji et al., 2024). In the context of physics learning, this competency plays an important role because it encourages students not merely to memorize formulas but to construct solutions to real problems through the *elaboration* of diverse ideas (Wafa et al., 2025). Research in several madrasahs shows that students tend to be passive, waiting for the teacher's instructions, and are not yet accustomed to expressing their own ideas, while learning is oriented mostly toward note-taking and memorizing content (Harahap & Sesmiarni, 2026).

A preliminary study conducted through an interview with the physics teacher at MAN 2 Agam confirmed that instruction has so far relied on conventional printed teaching materials and less varied learning models, so that students are used to merely observing and taking notes without being actively involved in the thinking process. Similar conditions have also been reported in various earlier studies, namely that teaching materials in the form of textbooks and conventional student worksheets (LKS) are considered insufficiently contextual and do not encourage students to build their own understanding (Suprihatin et al., 2024). The accumulation of these problems results in students' low creative thinking scores, which in one study were recorded at only 37.8, far below the Learning Objective Achievement Criteria (KKTP) of 65 (Malini et al., 2022).

Various teaching-material innovations have been proposed to address this problem. One rapidly developing direction is the digitization of teaching materials into electronic modules (e-modules), which offer flexible access, independent learning, and the ability to present content multimodally through text, images, audio, video, and animation (Baktiar & Hutapea, 2023). Earlier studies show that interactive *flipbook*-based e-modules can increase students' interest and enthusiasm for learning as a prerequisite for developing creative thinking ability (Safrilia & Satrio, 2025), while e-modules based on design-thinking projects combined with *augmented reality* (AR) have been proven useful for stimulating creativity (Puspita et al., 2024). AR technology itself allows students to observe three-dimensional visualizations of abstract physics concepts, making the material more concrete and contextual.

The topic of Work and Energy contains concepts that cannot be observed directly, such as energy as a quantity that changes form and work that depends on the magnitude of the force, the displacement, and the angle between them. In printed books, these phenomena appear only as static two-dimensional images, so students must imagine them on their own. AR has the potential to overcome this limitation because objects can be viewed from various angles and displayed in the real-world context around students. This visualization becomes material for thinking that can trigger questions, conjectures, and alternative explanations, which are prerequisites for creative thinking.

On the other hand, providing media alone is not sufficient without being guided by a learning model that explicitly targets creative thinking ability. The Treffinger model is a relevant candidate because it is conceptually designed to help students understand concepts while developing creative thinking ability through step-by-step problem solving (Novriandi et al., 2025). According to Shoimin (2014), the Treffinger model has three syntax stages, *namely*

Basic Tools, Practice with Process, and *Working with Real Problems*, which build a systematic connection between students' cognitive and affective abilities in encouraging creative learning (Nugraheni et al., 2019). Research applying Treffinger in other subjects, such as the development of a trigonometry module assisted by *Canva* and a trigonometry e-LKPD (electronic student worksheet), reported high validity and practicality; however, its application to a physics electronic module that simultaneously integrates AR on the topic of Work and Energy has not been widely studied specifically (Exzanti et al., 2025).

This study differs from previous AR-based e-module studies in several respects. First, in earlier studies AR functioned as a medium for visualizing concepts or as a project supplement, as reported by Salsabillah & Yanti (2025), whereas here AR is placed as part of the learning syntax, that is, AR objects are designed to trigger creative thinking activities at every stage, not merely to clarify concepts. Second, earlier Treffinger-based e-modules took the form of modules or student worksheets (LKPD) without the support of three-dimensional visualization (Exzanti et al., 2025), so abstract concepts at the *basic tools* stage were presented only through text and two-dimensional images.

A review of previous studies reveals a clear *research gap*. First, research on developing AR-based e-modules for physics generally focuses on the topics of Temperature and Heat, Sound Waves, Dynamic Electricity, or Momentum, while development on the topic of Work and Energy has not been widely explored with a similar approach. Second, studies applying the Treffinger model have so far been conducted mostly in mathematics, while its combination with AR-based electronic teaching materials in physics remains limited. Third, most previous studies assess the validity and practicality of the product separately, without explicitly linking them to the mapping of creative thinking indicators *(fluency, flexibility, originality, elaboration)* within the structure of the questions and learning activities developed. These three gaps form the basis of the *novelty* of this study, namely developing a physics e-module based on the Treffinger model integrated with AR on the topic of Work and Energy while also mapping the distribution of creative thinking indicators within it.

Based on the above description, this study aims to describe the development process of a physics e-module based on the Treffinger model integrated with Augmented Reality (AR) on the topic of Work and Energy, and to determine the quality of the developed product in terms of validity and practicality in facilitating the creative thinking ability of MA/SMA (Islamic senior high school/senior high school) students.

METHODS

This study used a Research and Development (R&D) approach, a method focused on creating or refining a particular product. The development model used was the Plomp model. The Plomp model was chosen because each of its phases requires evidence-based decisions, from needs analysis and formative evaluation to product assessment, making it suitable for answering the research objective, namely describing the development process and testing product quality at the validity and practicality stages. This model is iterative, in that the prototype is revised based on expert input before being tested (Dewantari et al., 2023).

The Plomp model consists of three main stages: (1) *preliminary research*, comprising a needs analysis of teachers and students and a literature review; (2) the *development of prototype phase*, which produces an e-module prototype validated by experts; and (3) the *assessment phase*, which measures the level of product practicality under real learning conditions. The development flow is presented in Figure 1.



Figure 1. The Plomp Model Development Procedure

Needs analysis was conducted through an interview with the physics teacher at MAN 2 Agam and a review of the Phase E Merdeka Curriculum, while the literature review focused on the theory of the Treffinger model, *augmented reality*, and creative thinking indicators. In the development stage, prototype I was designed using *Canva* as the main design platform, *Assemblr Edu* to build AR-based three-dimensional objects accessed by scanning QR codes, and *Heyzine Flipbook* to convert the module into an interactive *e-book* format that can be accessed via a link on Android devices, laptops, and computers. The material was arranged following the Treffinger syntax (*Basic Tools, Practice with Process, Working with Real Problems*) on the topic of Work and Energy for Grade X, Phase E.

The validity test was carried out by three expert validators from UIN Imam Bonjol Padang: the construction aspect was assessed by a construct expert, the content aspect by a physics content expert, and the language aspect by a language expert. The practicality test was conducted with one physics teacher who teaches physics in Grade X Phase E and 20 students of class X E3, Phase E at MAN 2 Agam as the subjects of a limited trial; Grade X students (15-16 years old) in Phase E are already at the formal operational stage and are therefore able to think scientifically and plan for the future. The instruments used were validation questionnaires (for validators) and practicality questionnaires (for the teacher and students) with a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Qualitative data in the form of suggestions and comments from validators, as well as open-ended responses from students and the teacher, were also collected as a basis for product revision.

The quantitative validity data were analyzed using the following percentage formula, with the data sourced from expert validators.

$$V\,\% = (f / N) \times 100\% \quad \text{.....(1)}$$

Description: V = validity or practicality value of the product; f = score obtained from the assessment; N = maximum possible score.

The quantitative practicality data were analyzed using the following percentage formula, with the data sourced from the teacher and student questionnaires.

$$P\% = (f / N) \times 100\% \text{.....(2)}$$

Description: P = validity or practicality value of the product; f = score obtained from the assessment; N = maximum possible score.

The resulting percentages were then converted into the interpretation categories in Table 1, according to (Baharizki et al., 2021) , which are:

Table 1. Criteria for Interpreting the Validity and Practicality Values of the Electronic Module

Score Interval (%)	Category
Very Invalid / Very Impractical	0-20
Invalid / Impractical	21-40
Fairly Valid / Fairly Practical	41-60
Valid / Practical	61-80
Very Valid / Very Practical	81-100

(Sugiyono, 2016)

The product is declared valid if the validity score is in the range of 61–100, and practical if the practicality score is in the same range.

In addition, a descriptive analysis of the distribution of questions was conducted based on the four creative thinking indicators, *fluency, flexibility, originality, and elaboration*, to determine the proportion of each indicator relative to all questions developed in the e-module, using the same percentage formula. The creative thinking indicator analysis was carried out by identifying each question according to the creative thinking ability indicator it measures, namely *fluency, flexibility, originality*, and *elaboration*. Next, the number of questions for each indicator was counted and then expressed as a percentage of the total number of questions, using the formula:

$$P = (f \ / \ N) \ \times \ 100\% \text{ .....(3)}$$

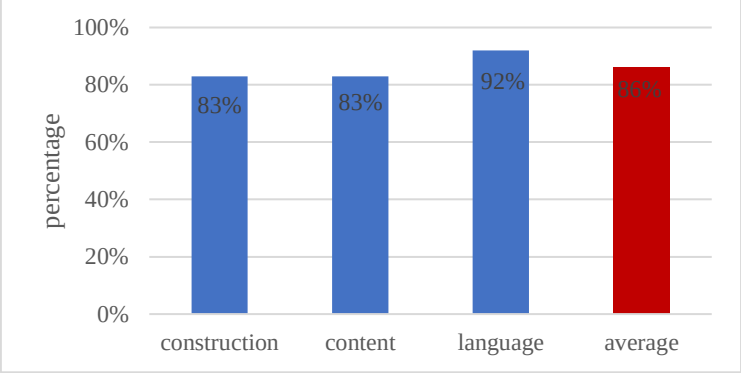
Description: P = *Percentage; f*= number of questions for each indicator; *N*= total number of creative thinking questions (Aulia et al., 2023).

RESULTS AND DISCUSSION

Research Results

The preliminary research stage revealed that the physics teacher at MAN 2 Agam had so far relied on printed teaching materials and conventional learning models that do not sufficiently facilitate students' creative thinking. This finding confirms the urgency of developing more interactive alternative teaching materials. The curriculum analysis showed that the topic of Work and Energy in Grade X Phase E of the Merdeka Curriculum is suitable as the development context because it contains many abstract concepts that can potentially be visualized through AR.

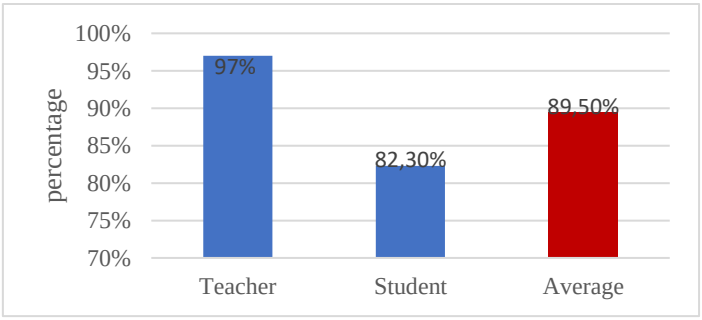
In the prototype development stage, the e-module was compiled with complete components, including a cover, usage instructions, a concept map, learning outcomes and objectives, the Treffinger model syntax, content descriptions, three-dimensional AR objects, a summary, an evaluation, a glossary, and a bibliography; the product was then uploaded to Heyzine flipbook so that students could access it online. Prototype I was then validated by experts on three aspects, namely construction, content, and language. The validation results are presented in Graph 1 below:



Graph 1. Results of the Validity Test of the Physics Electronic Module Based on the Construction, Content, and Language Aspects

The validity test was conducted on three aspects, namely construction, content, and language, by three different validators. The results of the validity test of the physics electronic module show that the construction aspect obtained a percentage of 83% in the very valid category, the content aspect obtained a percentage of 83% in the very valid category, and the language aspect obtained a percentage of 92% in the very valid category. Overall, the average validity percentage of the electronic module reached 86% in the very valid category. These results indicate that the developed electronic module meets the feasibility requirements in terms of construction, suitability of material and content, and use of language, so that it can be used as teaching material in physics learning after revisions in line with the validators' suggestions.

Prototype II was then tested on a limited basis to measure the product's practicality through questionnaires completed by one teacher (13 statements) and twenty students (10 statements). The results of the practicality test are presented in Graph 2 below:



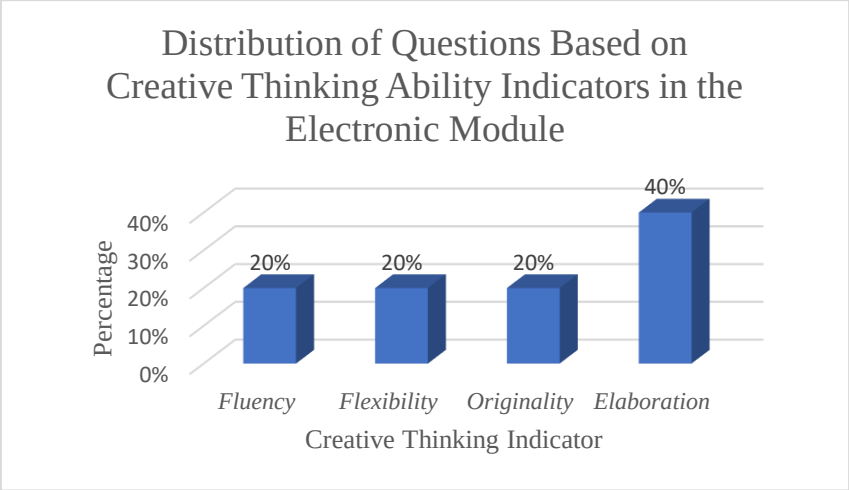
Graph 2. Results of the Practicality Test of the Physics Electronic Module by the Teacher and Students

The average practicality value of the product was 89.5% in the very practical category, consisting of a teacher assessment of 97% and a student assessment of 82.3%. The teacher's notes stated that the e-module was good and easy to understand, while some students stated that the AR media in the e-module made learning more interesting and made it easier to understand the material. The distribution of questions in the electronic module can be seen in Table 2 below:

Table 2. Distribution of Questions Based on Creative Thinking Ability Indicators

Creative Thinking Indicator	Number of Questions	Percentage
Fluency (idea flow)	3	20%
Flexibility (adaptability)	3	20%
Originality (uniqueness)	3	20%
Elaboration (detailing)	6	40%
Total	15	100%

Analysis of the distribution of questions across the four creative thinking indicators produced the results shown in Graph 3 below:



Graph 3. Distribution of Questions Based on Creative Thinking Ability Indicators

Discussion

The developed product is a physics e-module that combines the Treffinger learning model with *Augmented Reality* media on the topic of Work and Energy. The use of *Canva, Assemblr Edu, and Heyzine flipbook* aims to produce teaching materials that are engaging, interactive, and easily accessible via smartphones and computers. Through the AR feature, students can scan markers in the e-module to display three-dimensional objects so that the material can be observed more concretely, in line with the view that AR can combine the real and virtual worlds in real time to provide a more meaningful learning experience (Siregar et al., 2025).

The syntax of the Treffinger model, which consists of *basic tools, practice with process, and working with real problems*, is arranged systematically so that students not only understand

concepts but are also trained to develop creative ideas. In the *basic tools* stage, students are guided to identify problems and generate various alternative answers; in *practice with process*, students analyze concepts through discussion; and in *working with real problems*, students apply the concepts to real problems in their surrounding environment. This pattern is consistent with findings that the Treffinger model gives students the freedom to solve problems in their own way, thereby facilitating creative thinking step by step (Khairiah & Amir, 2021).

The construction validity score of 83% shows that the e-module has met the characteristics of being *self-instructional, self-contained, stand-alone, adaptive, and user-friendly,* although the layout aspects (spacing, margins, and consistency) and the introduction framework still need strengthening. This finding is in line with the view that media combining attractive visualization and three-dimensional interaction are highly suitable for increasing student engagement (Salsabillah & Yanti, 2025). The content validity of 83% indicates that the learning outcomes, learning objectives, and all media components already refer to the creative thinking indicators, as affirmed by the view that e-modules with evaluation stages and interactive components can encourage students to produce innovative solutions (Putri & Alberida, 2022). As for language validity, the 92% score shows that the language used is communicative and easy to understand, although slight improvements in spelling are still needed (Barasa et al., 2026). The highest score was on the language aspect (92%), indicating that the sentence structure and physics terminology are communicative, with only limited improvements needed in spelling. The construction and content scores were both 83%, at the lower boundary of the very valid category (81–100), so there is still room for improvement. For construction, the validators highlighted the layout (spacing, margins, consistency) and the introduction framework. For content, the completeness of the alignment among the learning outcomes (CP), learning objectives (TP), and module components with the creative thinking indicators needs to be strengthened.

In terms of practicality, the teacher's assessment of 97% indicates that the usage instructions, Treffinger syntax, learning objectives, material, example questions, and language in the e-module are easy to understand and can be used on various devices. This is in line with findings that integrating text, images, example questions, and AR objects proved to be very valid and practical, and made it easier for students to understand abstract concepts (Ayu et al., 2024). The student assessment of 82.3% confirms the same, with the highest score on the aspect of the learning video, which greatly helped understanding of the material, as found in similar research (Salamao et al., 2025).

The gap between the teacher's (97%) and the students' (82.3%) assessments deserves attention. The teacher assessed from the perspective of ease of use and suitability for learning, while students assessed from direct experience. The students' lower scores, especially on statements about the Treffinger syntax and AR media, indicate that these two core components of the product are precisely those most in need of improvement. One possible cause is that students are not yet accustomed to a syntax flow that requires them to generate their own ideas. Nevertheless, several statements indicate the need for further refinement so that creative thinking activities are more optimal, in line with the importance of AR in presenting physics phenomena concretely and interactively (Basir & Uding, 2025).

The distribution of questions across the four creative thinking indicators shows the dominance of the elaboration indicator (40%), followed by originality, fluency, and flexibility (15% each). The dominance of elaboration is consistent with the character of the Treffinger model, which gives students the freedom to detail ideas, connect physics concepts with everyday phenomena, and give scientific reasons for their answers (Khairiah & Amir, 2021). A similar pattern was also found in the application of the Treffinger model at other education levels, showing that the elaboration indicator tends to achieve the highest results because students are trained to enrich and detail ideas in solving problems (Zega et al., 2022). Meanwhile, the fluency, flexibility, and originality indicators are still accommodated through questions that require students to generate various alternative solutions and unique ideas, so that overall the e-module covers all aspects of creative thinking ability, albeit with different emphases.

Overall, the validity results (86%) and practicality results (89.5%), categorized as very valid and very practical, show that the physics e-module based on the Treffinger model and *Augmented Reality* can serve as an alternative teaching material to hone the creative thinking ability of MA/SMA students on the topic of work and energy.

CONCLUSION

A physics e-module using the Treffinger model based on *Augmented Reality* for the creative thinking ability of MA/SMA students on the topic of work and energy was successfully developed using the Plomp model through the stages of preliminary research, prototype development, and assessment. The product is a flipbook designed with Canva, combined with AR objects from *Assemblr Edu*, and applying the *basic tools, practice with process, and working with real problems* syntax of the Treffinger model. The quality test results show that the product meets the very valid criterion, with an average validity of 86% (construction 83%, Content 83%, Language 92%) and the very practical criterion, with an average practicality of 89.5% (teacher 97% and students 82.3%). Thus, this e-module can facilitate students' creative thinking ability in physics learning. It also opens opportunities for further research to test its effectiveness through an experimental design.

AUTHOR CONTRIBUTIONS

Mutia Rahmi contributed to conceptualization, methodology, investigation, data curation, formal analysis, and writing original draft preparation. Raudhatul Jannah contributed to conceptualization, methodology, supervision, validation, and writing review and editing. Pipi Deswita contributed to investigation, validation, visualization, and writing review and editing. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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