Team Based Project-Differentiation Learning and AppYet e-Module to Improve Pre-service Teacher's Creativity

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***Abstract*—Creativity is an essential competence for pre-service teachers in preparing innovative learning designs that meet diverse student needs. However, many pre-service teachers face challenges in developing creative skills due to limited opportunities for collaborative and differentiated learning experiences. This study aims to investigate the effectiveness of Team-Based Project-Differentiation Learning supported by an AppYet based e-module (TBP-DIFLAE) in improving pre-service teachers' creativity. The study employed a quasi-experimental design with a non-equivalent control group involving 51 pre-service physics teachers at a teacher education institution. The experimental group participated in TBP-DIFLAE principles, while the control group received conventional instruction. Creativity was assessed using a validated analytic rubric aligned to TBP-DIFLAE tasks, operationalizing (1) the ability to generate original ideas (novel/low-frequency responses), (2) confidence in solving problems independently (self-directed solution planning and execution), and (3) skill in further developing other ideas (actionable extensions/refinements), with each dimension scored on a 0–4 scale. The findings show that the experimental group achieved a significant improvement in creativity (*N*-Gain = 0.38, middle effect size, $p < 0.05$) compared to the control group. The study concludes that the integration of TBP-DIFLAE significantly enhances pre-service teachers' creativity. Despite positive gains, the single-institution and modest sample limit generalizability; future multi-site research with larger, more diverse, and cross-disciplinary cohorts is warranted to validate and extend these findings. These findings provide practical insights for teacher education programs, highlighting the potential of combining technology and collaborative-differentiated strategies to foster creativity and prepare future teachers for 21st-century educational challenges.**

***Keywords*—team based project, differentiated, e-module, pre-service teacher's, creativity**

I. Introduction

In the era of disruption, education has undergone a massive shift and transformation, affecting systems, administrative processes, and technical aspects [1]. This disruption has diminished the role of educators, who are no longer seen as crucial elements within the educational dimension, while learning activities are no longer bound by space and time [2, 3]. In other words, the foundations of conventional educational systems have begun to erode, transitioning toward a new, digitally based educational system [4]. Along with the advancement of digital technology in Indonesia and in response to students' needs within the full-day school curriculum policy, various alternative digital media have emerged to reach students—not in violation of the system, but rather as tools to meet students' needs for more efficient and effective learning [5]. It can be concluded that education is experiencing a significant shift toward a digital-based system that is transforming the role of educators and learning patterns, while giving rise to various alternative digital media that support the efficiency and effectiveness of learning, particularly in meeting students' needs.

In addition to addressing the digitalization of learning, pre-service teachers who will become future educators must also be capable of integrating teaching materials in digital form [6, 7]. Beyond using information technology to support classroom learning processes, teachers must be able to develop engaging and innovative teaching materials, as this is an essential attribute of a professional educator [8]. This is particularly important given that the development of teaching materials makes a significant contribution to the success of the learning process [9]. In line with the progress of the times, in this era of the Industrial Revolution 4.0, the development of digital-based teaching materials has become a necessity for teachers and educators [5, 10]. Based on these statements, it is clear that in the Industrial Revolution 4.0 era, pre-service teachers must possess professional competencies to integrate and develop engaging and innovative digital-based teaching materials, considering their vital role in supporting the success of the learning process.

The ability to develop digital teaching materials must align with improvements in students' conceptual understanding. This means that the digital teaching materials created by pre-service teachers should not only follow technological developments but must also be adapted to support students' mastery of concepts. Concepts play a key role in the formation of scientific knowledge. A person's ability to identify characteristics or classify objects and events in their surroundings requires conceptual mastery [11]. Conceptual mastery is defined as students' ability to understand meaning in a scientific sense, both in terms of theory and its application in daily life. It reflects students' efforts to absorb and transfer information from specific learning content, which can be used to solve problems, conduct analysis, and interpret phenomena. With strong mastery of physics concepts, students will be better supported in facing and solving various problems [12–16].

Facing the future era of education requires not only improving conceptual understanding, but also fostering creative thinking skills [17]. Future education must focus on developing skills such as critical thinking, collaboration, communication, and creativity. These skills are essential for preparing students to face complex challenges in an ever-changing workforce [18]. Creativity allows students to think innovatively and generate new solutions to existing problems. By enhancing their creativity, students can develop the problem-solving and critical thinking skills needed to handle complex situations [19]. The digital era offers great opportunities to integrate technology into education. The use of digital learning platforms can enhance interactivity and student engagement, as well as facilitate the development of their creativity. In facing the global job market, education must be able to produce graduates who not only master theoretical knowledge but also possess practical and innovative skills. Creative thinking skills are a crucial aspect in preparing the younger generation to adapt to change [18].

However, based on the researcher's observations in the microteaching course in class PSF 21, whose students are all pre-service teachers conducting microteaching practice, it was found that among the 9 students, only 85% were familiar with digitalization in teaching material development, such as using Google Sites, Heyzine, Canva, Flip PDF Professional, and similar tools. Nevertheless, on average, the students were only familiar with digital teaching materials in the form of websites, while those based on applications were entirely unfamiliar. This was evident as none of the 9 students had ever developed teaching materials using applications, citing that it would take too much time to learn how to create an application containing instructional content. In addition, as future teachers, it is not only pedagogical skills that need to be improved; all four teacher competencies must be strengthened, one of which is professional competence (the ability to understand concepts). Based on the students' conceptual understanding test administered online, it was found that out of 9 students, only 2 scored in category B, 3 in category C, and 4 in category E. This indicates that students' physics conceptual understanding is still in the low category. A follow-up test of students' creative thinking skills also showed low results, as evidenced by only 1 student falling into the medium category, while the remaining students were in the low category. Based on these findings, it can be concluded that although most students are familiar with digitalization in the development of teaching materials, their experience is limited to the use of websites, and they have never developed application-based teaching materials due to constraints in time and skills. In addition, the professional competence of pre-service teachers, particularly their physics conceptual understanding and creative thinking skills, is still relatively low. Therefore, efforts are needed to enhance all four teacher competencies, with particular focus on improving pedagogical and professional abilities.

A solution to address this issue is to develop digital physics teaching materials by utilizing an Android-based application such as AppYet. AppYet is an online service that allows users to create Android applications without requiring programming skills. The platform supports various features, including Really Simple Syndication (RSS)/Atom, HTML5, podcasts, YouTube, TapaTalk, forums, Twitter, and Mapbox. This makes it highly suitable for educators, as many students own smartphones, thereby facilitating the use of technology in the learning process [20]. In developing teaching materials using AppYet, the first step is to access the AppYet platform and create a new project. Once the project is created, modules can be added to the application by selecting the appropriate module type, such as an RSS feed or HTML content. Configure the module by setting details such as the feed URL or the content to be displayed. AppYet provides an intuitive interface for customizing the module's appearance, including options to adjust colors, fonts, and layout. After completing the configuration, save the changes and preview the application to ensure that the modules function as intended. Finally, after testing and making any necessary adjustments, the application can be published on the Google Play Store or other app distribution platforms [21, 22]. It can be concluded that the use of Android applications such as AppYet can be an effective solution for developing digital physics teaching materials. AppYet enables educators to create learning applications without requiring programming skills, offering features that support educational content and are easily accessible via students' smartphones. The application development process involves intuitive steps, starting from creating a new project, adding and configuring modules, to publishing the application on distribution platforms such as the Google Play Store.

In addition to the ability to develop digital teaching materials, solutions are also needed to enhance students' understanding of physics concepts and creative thinking skills, which they can later transfer to their own students as future teachers. The proposed solution is to use digital teaching materials developed with the AppYet application, based on Team-Based Project (TBP) learning, which essentially incorporates the phases of project-based learning within it. This is supported by several references, which state that project-based learning can improve conceptual understanding and creative thinking skills. Specifically, Refs. [23–26] report that project-based learning has been proven to enhance students' understanding of mathematical concepts. Students are able to think critically and creatively in solving problems relevant to the subject matter, and they can repeatedly revisit and deepen their understanding of the material as they generate ideas, design projects, and refine them. This approach allows students to apply concepts directly and to consolidate their understanding as they work to produce a tangible product.

The digital teaching materials developed are integrated with the Merdeka Curriculum. The Merdeka Curriculum is a curriculum that offers diverse intraclass learning, with content optimized to provide students sufficient time to explore concepts in depth and strengthen their competencies. Teachers have the flexibility to choose from a variety of teaching tools, allowing instruction to be tailored to students' learning needs and interests [27]. In this study, the differentiation approach is integrated with team-based projects in the hope that students will have the freedom to express their abilities and creativity according to their individual learning styles.

This study is situated in the South Sumatra region of Indonesia and focuses on pre-service physics teachers in a Physics Education program (n = 51). While prior work supports project-based and differentiated approaches, there remains a research gap regarding a Team Based Project-Differentiation Learning and AppYet E-Module (TBP-DIFLAE) model, and evaluated comprehensively through validity, practicality, and effectiveness. Our work addresses this gap by combining educational design research with a quasi-experimental comparison (TBP-DIFLAE vs. conventional instruction) and by assessing creativity with indicators tailored to teacher-education contexts.

Project-based pedagogies and differentiated instruction have been increasingly adopted in physics education to promote higher-order thinking and learner agency. In the Indonesian Merdeka Curriculum, programs are encouraged to provide flexible, in-depth exploration with technology-enhanced resources. Building on these directions, AppYet based e-modules offer structured, offline-capable content, diagnostic routing by learning style, and embedded worksheets/rubrics that are suitable for team-based studio work. Within pre-service Physics Education programs, these affordances align with the need to develop creativity and self-directed problem solving through authentic, collaborative projects.

Despite these advances, there is limited quasi-experimental evidence on TBP-DIF enacted through an AppYet e-module and evaluated with the full validity, practicality, effectiveness triad in the Merdeka Curriculum context. Prior reports often describe design or feasibility but rarely combine: (i) expert-validated instruments and rubrics; (ii) classroom practicality tracked across phased TBP procedures; and (iii) effectiveness on creativity outcomes operationalized for teacher education (ability to generate original ideas, confidence in solving problems independently, and skill in further developing other ideas) [28–30]. Addressing this gap, the present study involves pre-service physics teachers and examines whether TBP-DIFLAE, delivered via AppYet, achieves strong validity and practicality while producing measurable gains in creativity compared with conventional instruction.

The research questions in this study will examine detailed questions about TBP-DIFLAE on creativity. The questions primarily focused on: 1) What is the content/construct validity of the TBP-DIFLAE model and AppYet e-module? 2) How practical is TBP-DIFLAE across its six phases based on classroom implementation percentages. 3) Does TBP-DIFLAE outperform conventional instruction in creative thinking?

II. Materials and Methods

A. Research Design

This study applied an Educational Design Research (EDR) approach combined with a quasi-experimental method [31]. The research process was conducted in stages involving the design, pilot testing, revision, and full implementation of a TBP-DIFLAE, in collaboration with practitioners. The EDR phase focused on iterative refinement of the e-module through feedback obtained from pilot sessions, while the quasi-experimental phase evaluated its effectiveness in enhancing pre-service teachers' creativity. The participants consisted of two groups of pre-service physics teachers receiving different treatments: the experimental group applied TBP-DIFLAE, while the control group received conventional, individual-based instruction without digital or project-based components. The study was conducted from February to May 2025 in one University in South Sumatra Province, Indonesia. A total of 51 participants were involved, determined using the Slovin formula based on the population of the physics education program. Sampling was conducted using cluster sampling based on pre-assigned classes by the University. The intervention was delivered over eight sessions (16 hours in total). The sample was divided into 29 students in the experimental group and 22 students in the control group.

B. Research Instruments

The instruments used in this study included lesson plans, worksheets, the AppYet e-module, validation sheets, observation sheets, and creativity assessment sheets. In the experimental class, the TBP-DIFLAE learning model was implemented following six phases: (1) Identifying essential questions, (2) Designing project planning, (3) Developing a schedule, (4) Monitoring project progress, (5) Assessing outcomes, and (6) Evaluating the experience. Each phase was integrated with a differentiated learning approach and the AppYet e-module. In contrast, the control class employed conventional instruction through listening to explanations, concept presentations, and class discussions. The AppYet e-module developed was designed exclusively for Android mobile platforms in .apk format, with a file size of 55.78 MB, and it was only accessible online. Fig. 1 presents several sample displays of the AppYet e-module. The AppYet e-module is equipped with a learning style diagnostic test, instructional materials, and worksheets tailored to each learning style, aligned with the phases of the team-based project model. It also features an evaluation tool designed to measure levels of creativity. Two types of tests were used: a pretest and a posttest, both developed based on indicators of creative thinking skills. These indicators encompass three criteria: (1) the ability to generate original ideas, (2) confidence in solving problems independently, and (3) skill in further developing other ideas [32]. Each indicator comprises 3 to 4 questions. A validation questionnaire was administered to assess the feasibility of the TBP-DIFLAE model in learning, using a 5-point Likert scale, where 1 = very poor and 5 = very good.

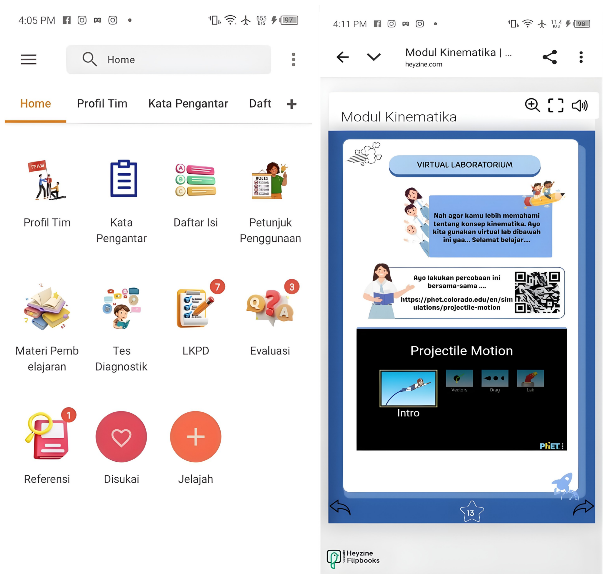

Fig. 1. Interface screenshots of the AppYet e-module.

C. Data Collection

As shown in Fig. 2, the data collection process in this study comprised three stages: validity, practicality, and effectiveness. It began with an analysis of the problems and needs related to the product to be developed, followed by the design of TBP-DIFLAE as a proposed solution. To ensure the quality of the product, validation, practicality, and effectiveness tests were conducted. The validation test involved two physics education experts and one physics content expert to assess the content and construct validity of TBP-DIFLAE and its supporting instruments using validation sheets. Feedback from the experts was used to revise the product until TBP-DIFLAE was deemed feasible for implementation.

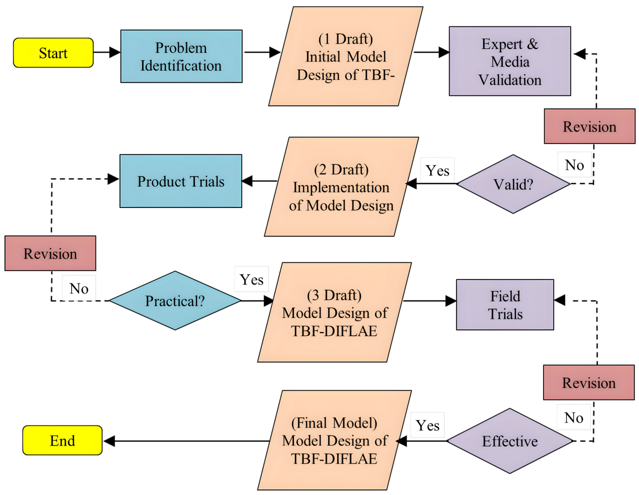

Fig. 2. Research flow [33, 34].

The practicality of the TBP-DIFLAE model refers to the extent to which the model can be implemented, as measured through an observation instrument. Observations were conducted by two observers: an associate professor and a subject matter expert lecturer. The level of model implementation reflects the performance of pre-service teachers during the trial phase and indicates the alignment between the instructional stages and the lesson plan. The model is considered practical if its implementation level falls at least within the "practical" category.

Effectiveness was measured based on the quality of the learning model in enhancing creative thinking skills, which was analyzed through pre-test and post-test results. The study employed a nonequivalent conventional group design consisting of two classes: experimental and traditional. Both classes initially demonstrated comparable levels of creative thinking, as confirmed by a homogeneity test. At the outset, both groups were given a pre-test to measure baseline abilities. The experimental class then received instruction using the TBP-DIFLAE model, while the traditional class received conventional instruction through lectures, discussions, and assignments. After the instructional period concluded, both classes were administered a post-test to assess their final creative thinking skills, and only the experimental class was asked to complete a response questionnaire. The test items were developed based on a creative thinking assessment rubric, which included the following indicators: the ability to generate original ideas, confidence in one's own problem-solving abilities, and skill in further developing other ideas [32].

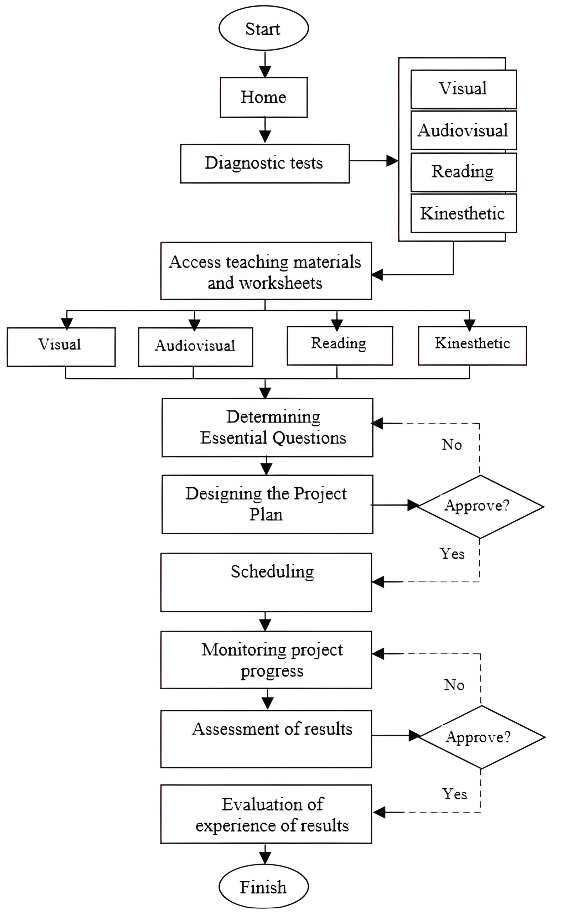

Fig. 3. Teaching procedures of TBP-DIFLAE.

Data collection flow and alignment with procedures, to ensure procedural fidelity, data collection was aligned to each phase in the TBP-DIFLAE flowchart (Fig. 3). Specifically: (a) Validity evidence was gathered during the design and development phases (expert review sheets, Aiken's V); (b) Practicality evidence during the implementation phase (teacher logs, student response sheets, observer checklists mapped to each node in Fig. 3); and (c) Effectiveness evidence at the evaluation phase (pre-post tests and N-Gain).

D. Data Analysis

The validation data were analyzed using Aiken's V formula, based on expert evaluations for each assessed aspect using a Likert scale score. After the experts completed their assessments on the validation sheets, the Aiken's V coefficient was calculated for each aspect evaluated. In this assessment, there were two raters using a five-point rating scale. According to Aiken's criteria, an item is considered valid if the Aiken's V index falls within the range of 0 to 1. An item is deemed acceptable if it meets the required validity threshold, which depends on the number of raters and the rating scale used, as presented in Table 1 [35].

Table 1. Classification of Aiken's validity coefficient

Values of Aiken's Validity Coefficient (V)	Category
$0 < V \leq 0.4$	Low Validity (Weak)
$0.4 < V \leq 0.8$	Moderate Validity (Middle)
$0.8 < V \leq 1$	High Validity (Strong)

The practicality data were analyzed using a qualitative descriptive approach, based on the observation results of the TBP-DIFLAE implementation. Data obtained from the two observers were analyzed by recapitulating the results in the form of a checklist, structured using a Guttman scale table, where a "yes" response was scored as 1 and a "no" response was scored as 0. After calculating the percentage for each category, the next step was to classify the scores, convert them into percentages, and then interpret the results using statements similar to those presented in Table 2 [36]. The instrument is deemed practical if the observation results achieve a minimum classification of "practical".

Table 2. Practicality criteria

No	Percentage	Practicality Criteria
1	86–100	Highly Practical
2	76–85	Practical
3	60–75	Moderately Practical
4	55–59	Less Practical
5	0–54	Not Practical

The effectiveness of the learning process was determined based on the following criteria: (i) students' creative thinking skills scores fall within the medium (adequate) category, (ii) the N-gain score is within the medium level category, (iii) there is a significant difference in students' creative thinking skills between the pretest and posttest, (iv) the effect size is within the medium category, and (v) there is a significant difference in creative thinking ability between the two classes [33, 37]. With a note that the significance in this study was determined using a t-test. The level of creative thinking skills was categorized accordingly [38], N-gain [39] and the effect size [40] can be observed in Table 3.

Table 3. Determination of creative thinking skills, N-gain, effect size

Creative thinking skills		N-Gain		Effect Size	
Score Range	**Creativity Level**	**N-Gain Range**	**N-Gain Level**	**Effect Size Value**	**Effect Size Level**
0–40	Not creative	$\langle g \rangle < 0.3$	Low	0.2	Small
41–55	Less creative	$0.3 \leq \langle g \rangle \leq 0.7$	Medium	0.5	Medium
56–65	Quite creative	$\langle g \rangle > 0.7$	High	≥0.8	High
66–80	creative				
81–100	Very creative				

III. Result and Discussion

A. Validity

The validation was carried out by two validators: one expert in physics education and one expert in pure physics. They evaluated the content and construct of the instrument using a 5-point Likert scale assessment sheet (1 = very poor to 5 = very good). The scores provided were converted into Aiken's V index for each assessed aspect/component, and the results are summarized in Table 4.

Table 4. Validation assessment results

Instrument	Σs	n	V	Classification
Lesson Plan	31	2	0.86	High Validity
Worksheet based DIFLAE	34	2	0.94	High Validity
AppYet e-module—content	32	2	0.89	High Validity
AppYet e-module—Look & Navigation	30	2	0.83	High Validity
Creativity Assessment Instrument	29	2	0.81	High Validity
Implementation Observation Instrument	28	2	0.78	Moderate Validity

Note: Σs refers to the sum of the differences between each validator's score and the minimum score on the scale, n = number of validators

Aiken's V index ≥ 0.86 for the lesson plan, Worksheet based DIFLAE, and AppYet e-module in terms of content indicates that the learning objectives, materials, and project activities are consistent with the learning outcomes and the characteristics of team-based project differentiation learning. This confirms that the developed instructional tools meet the "highly valid" standard, in line with previous findings on the development of differentiation-based instructional tools, which generally demonstrate a high level of validity. For instance, the validity of Worksheet based DIFLAE in other studies reached 88–91%, categorized as highly valid [41]. The validators also highlighted that the creativity indicators—originality, self-confidence, and idea development—were appropriately aligned with the assessment rubric. The emphasis on these indicators is consistent with prior studies suggesting that originality is the primary indicator of creativity, followed by idea development, fluency, and self-confidence [42, 43]. For instance, in studies on Project-Based Learning, creativity indicators such as originality, self-confidence, and the ability to develop ideas have also been shown to be consistently measurable through validated instruments [44, 45]. Minor revisions regarding the phrasing of question instructions are common findings during the instrument validation phase. As reported in several previous studies on the development of modules and worksheets, such revisions typically focus on improving the clarity of instructions and language to ensure the instrument is easily understood by students, without altering the fundamental substance of the assessment [46, 47].

The validity score of the AppYet e-module component, which obtained V value of 0.83, indicates that aspects such as menu layout, icons, and color scheme were rated positively. However, the validators noted important issues regarding color contrast in dark mode and the need for offline access to learning materials. Contrast issues in dark mode and color palette selection have frequently been highlighted in previous studies on e-module design, where color adjustments are recommended to improve visual comfort and readability [48]. In addition, limited access to materials due to reliance on internet connectivity is also a common issue in prior research. Solutions such as adding core material download features or offline caching have proven effective in enhancing user independence and learning flexibility [49, 50]. By incorporating improvements through color palette adjustments and download options, the development of this e-module aligns with best practice recommendations established in previous studies, while also enhancing the user experience in response to technological demands and modern learning needs.

A validity score of $V = 0.78$ for the Implementation Observation Instrument indicates moderate validity, but further refinement is needed to improve inter-rater consistency—particularly through the inclusion of differentiation indicators for content, process, and product, as well as clearer descriptions of the scoring scale. This recommendation aligns with previous studies that emphasize the importance of comprehensive indicators and clearly defined rating scales to ensure that observation instruments produce reliable and consistent data across observers. Several studies have also reported that unclear indicators and vague scoring scales are major factors contributing to low data consistency in observations, making such improvements crucial for enhancing the practicality and accuracy of measurement during the instrument trial phase [51, 52]. Therefore, the proposed revisions not only strengthen the instrument's validity but also follow best practices in the development of educational observation instruments.

B. Practicality

The practicality of the TBP-DIFLAE was analyzed based on implementation observations conducted by two independent observers: an associate professor and a subject matter expert lecturer. Observations were systematically carried out over eight class sessions, focusing on the implementation of each phase of the TBP-DIFLAE model as outlined in the lesson plan. Each phase of the learning model was well-structured in alignment with activities designed to enhance the creative thinking skills of pre-service physics teachers (Table 5). The observational data were analyzed using a qualitative descriptive approach with a Guttman scale, in which each indicator was assessed with a "yes" (score = 1) or "no" (score = 0) response. The results indicated that most indicators across all implementation phases of the TBP-DIFLAE model were effectively carried out. The average implementation percentage from both observers reached 86% (Table 6), which, according to the classification in Table 2, falls under the "highly practical" category.

Table 5. Implementation of TBP-DIFLAE on creative thinking skills

TBP-DIFLAE	Activity	Creative Thinking Skills
Determining Essential Questions	In groups, students explore central issues and develop open-ended questions to guide their projects, tailored to their learning styles through the AppYet e-module.	• the ability to generate original ideas • confidence in solving problems independently
Designing the Project Plan	Students design project implementation stages, develop solution strategies, and assign group roles based on their learning styles in the AppYet e-module application.	• confidence in solving problems independently • skill in further developing other ideas
Scheduling	Through the AppYet e-module, students develop a project timeline and allocate time for brainstorming, research, implementation, and evaluation phases.	• confidence in solving problems independently
Monitoring project progress	Lecturers and students collaboratively reflect on project progress, identify challenges encountered, and evaluate the effectiveness of work strategies according to individual learning styles via the AppYet e-module.	• skill in further developing other ideas • the ability to generate original ideas
Assessment of results	Students present their project outcomes according to their learning styles and receive feedback from the lecturer and peers through the AppYet e-module.	• confidence in solving problems independently • skill in further developing other ideas
Evaluation of experience	Through the AppYet e-module, students reflect on their learning journey by articulating key insights gained, challenges faced, and the creative solutions they formulated.	• skill in further developing other ideas • the ability to generate original ideas

Table 6. Results of the implementation assessment of TBP-DIFLAE

TBP-DIFLAE phase	Average Percentage of Both Observers	Category
Determining Essential Questions	89%	Highly Practical
Designing the Project Plan	86%	Highly Practical
Scheduling	83%	Practical
Monitoring project progress	89%	Highly Practical
Assessment of results	87%	Highly Practical
Evaluation of experience	80%	Practical
Average	86%	Highly Practical

The research findings indicate that Phase 1 (formulating essential questions) and Phase 4 (monitoring project progress) achieved the highest implementation scores of 89%, reflecting the active participation of prospective physics teachers from the initial planning to the project execution stages. This aligns with the principles of project-based learning, which emphasize authentic engagement of pre-service teachers [53, 54]. The success in the monitoring phase also demonstrates their ability to manage the learning process effectively, thereby enhancing self-regulation and collaboration skills [55, 56]. However, the evaluation phase (Phase 6) received the lowest score of 80%, as some groups were unable to conduct in-depth reflection during the group feedback sessions. This is a critical aspect for internalizing learning experiences and planning future improvements [57]. Such limitations may be attributed to the limited reflective experience of prospective teachers and the lack of concrete evaluation guidance within the AppYet e-module. These findings are consistent with prior studies that identified reflection as a persistent challenge in project-based learning [58, 59]. Therefore, the development of instructional strategies that explicitly teach reflective skills and the optimization of the AppYet e-module features are necessary to strengthen the evaluation process and support the holistic development of creativity among prospective teachers.

The practicality of the TBP-DIFLAE model is supported by the lightweight e-module (55.78 MB) that is easily accessible to prospective physics teachers and accommodates various learning styles. The AppYet e-module offers structured navigation through project phases, learning style assessments, and creativity evaluations, facilitating the effective implementation of the learning model in the classroom. Recent studies have shown that project-based learning e-modules are highly effective in enhancing student engagement, learning motivation, and creativity by providing structured learning experiences tailored to individual needs [60–62]. One of the key advantages of e-modules such as AppYet lies in their ability to support self-directed learning by offering interactive learning materials that are easy to access and use, thus making the learning process more efficient and dynamic [22]. Nevertheless, challenges remain, particularly in fostering deep reflection and optimizing feature utilization. These aspects need to be continuously developed to strengthen creativity and enable meaningful evaluation within project-based learning teams.

The successful implementation of this model is also reflected in the observers' comments, which noted that the instructional structure was well-organized, the instructor had clear guidelines, and students were able to follow the learning sequence actively and collaboratively. This indicates that the developed product is not only theoretically sound (validity) but also practical and easily implementable in real-world settings (practicality). Therefore, it can be concluded that the TBP-DIFLAE model is highly practical for application in the context of pre-service physics teacher education, particularly in efforts to develop creative thinking skills through collaborative, differentiated, and technology-integrated learning.

C. Effectiveness

The score criteria for pre-service teachers' creative thinking skills falling into the medium category serve as the first indicator of effectiveness. The results of the pretest and posttest of creative thinking skills are presented in Table 7.

Table 7. Pretest, posttest creativity scores

Class	N	Pre-Post	Creativity Scores	Category	St-Deviasi
Experiment	29	Pretest	48.6	less creative	7.4
		Posttest	68.2	creative	
Control	22	Prettest	49.3	less creative	6.8
		Posttest	52.7	less creative	

Descriptive analysis of the pretest scores in both classes showed that the students' creative thinking skills were still in the "less creative" category. This aligns with the findings of Husna and Kurniasih [63] which stated that, in general, students' creative thinking skills in Indonesia remain relatively low. The two classes were given different treatments: the experimental class received instruction using the TBP-DIFLAE model, while the control class was taught without it. Subsequent to the post-test, the results indicated that the average creativity score in the experimental group was 68.2 (SD = 7.4), which falls within the range of 66–80 and is categorized as "creative" or medium level. In contrast, the control group obtained a mean score of 52.7 (SD = 6.8), classified as "less creative". As the post-test score of prospective physics teachers in the experimental class reached the "creative" or medium category, the first criterion of effectiveness was achieved. The second effectiveness indicator, based on the minimum N-gain falling within the "medium" category, was also met. The N-gain value from pretest to posttest in the experimental class was 0.38, which is considered medium. Furthermore, when the N-gain was analyzed by each indicator (Fig. 4), it was found that the experimental class showed higher N-gain values across all three creativity indicators compared to the control class. This confirms that the second effectiveness criterion was also achieved.

The third effectiveness criterion is that the students' creative thinking skills show a significant difference between the pretest and posttest. As shown in Table 7, the results of the paired-samples t-test conducted to examine the difference between the pre-test and post-test scores in the experimental group indicate a statistically significant difference ($t(29) = 6.47$; $p = 0.000 < 0.05$). Thus, the third effectiveness criterion has been achieved.

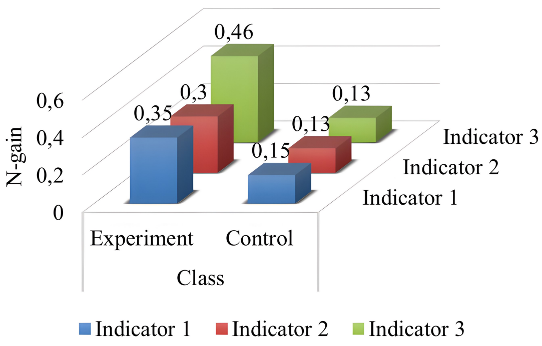

Fig. 4. N-gain for each indicator of creative thinking.

A clearer comparison of the average scores of creative thinking skills based on the three indicators (originality, self-confidence, and idea development) between the experimental and control classes, both before (pretest) and after (posttest) the TBP-DIFLAE learning implementation, can be seen in Diagram 1. It is evident that the experimental class showed greater improvement in all indicators compared to the control class. The most significant difference occurred in the idea development indicator, followed by originality. Although the control class also experienced some improvement, it was relatively smaller and tended to be stagnant compared to the experimental class.

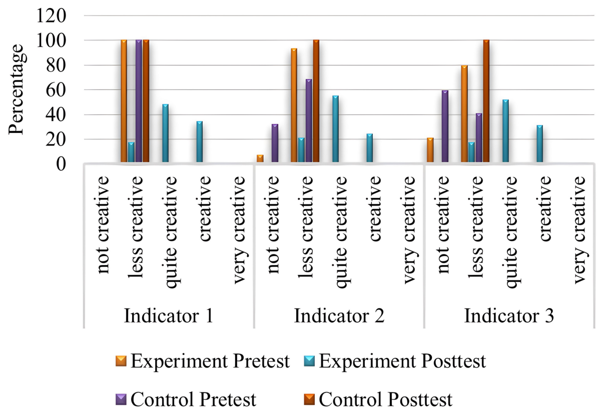

Fig. 5. Creative thinking for each indicator.

The next criterion of effectiveness is reviewed from the effect size and the significant difference in creative thinking skills between the two classes, which is examined through the t-test. Since the statistical test used is parametric, prerequisite tests were first conducted, namely the normality test and homogeneity test. The results of the normality test, homogeneity test, t-test, and effect size can be seen in Table 8.

Table 8. Normality test, homogeneity test, t-test, and effect size

Class	Normality test		Homogeneity test		t-test	Effect Size	
	p-value	Category	*p*-value	Category	*p*	Cohen's d	Category
Experiment	0.13	Normal	0.17	Homogenous	0.015*	0.38	Medium
Control	0.19	Normal					

Note: $*p < 0.05$

Based on the results obtained, the effect size was 0.38, which falls into the medium category, and there was a significant difference in creative thinking skills between the two classes as evidenced by the t-test. This fulfills the fourth and fifth criteria of effectiveness. Therefore, it can be concluded that TBP-DIFLAE is effective in improving the creative thinking skills of prospective physics teachers.

The implementation of TBP-DIFLAE can enhance the creative thinking skills of prospective teachers because all of its activities are aligned with the three indicators of creative thinking. The effectiveness of the TBP-DIFLAE learning model in improving the creative thinking skills of prospective physics teachers can be clearly observed through several key indicators in this study. Initially, the pretest scores in both classes were in the "less creative" category. However, after the intervention using TBP-DIFLAE, the experimental class showed a significant improvement, with the average posttest score rising to the "moderately creative" category, while the control class experienced only a minimal increase and remained in the "less creative" category. This confirms that the TBP-DIFLAE model is capable of bringing about a meaningful change in creativity levels, in line with Guilford's theory that creativity can be developed through systematic and collaborative learning interventions [64, 65].

In addition, from a quantitative perspective, the N-gain in the experimental class reached 0.38 (medium category), which was significantly higher than that of the control class, which only reached 0.06 (low category). This significant N-gain also reinforces previous research by Treffinger, who emphasized the importance of differentiated learning stimuli and team-based project learning in fostering students' creativity [66]. The t-test showed a significant difference between the pretest and posttest scores in the experimental class ($p = 0.000 < 0.05$), and the between-group t-test yielded a p-value of 0.015 with an effect size of 0.38 (medium category). These findings are consistent with previous studies indicating that team-based project learning significantly enhances students' originality, self-confidence, and ability to develop ideas [61].

Overall, the TBP-DIFLAE model has proven to be effective in enhancing creative thinking skills, demonstrating its effectiveness both statistically and through the aligned improvement of creative thinking indicators. This effectiveness aligns with 21st-century innovative learning models that emphasize collaborative activities, open-ended problem-solving, and differentiated learning based on individual needs. Therefore, the implementation of TBP-DIFLAE is highly recommended for further development as one of the main strategies in physics teacher education to optimally foster creative thinking potential in the current era of modern education.

IV. Conclusion

In terms of validity, all learning tools and instruments developed were declared valid, with most falling into the highly valid category, as indicated by Aiken's V values ranging from 0.78 to 0.94. This high validity demonstrates that the content, structure, and indicators within the tools are in accordance with the principles of project-based differentiated learning and support the measurement of creative thinking indicators such as originality, self-confidence, and idea development. In terms of practicality, the TBP-DIFLAE model showed excellent implementability, with an average implementation percentage of 86%. The model was consistently implemented by lecturers and actively followed by students, supported by a systematic learning structure and the AppYet e-module features that promote independent and flexible learning styles. Regarding effectiveness, the TBP-DIFLAE model proved effective in improving the creative thinking skills of prospective physics teachers. This is evidenced by the improvement in creativity scores from the "less creative" to "creative" (medium category), an N-gain of 0.38 (medium category), a significant t-test result ($p < 0.05$), and an effect size of 0.38 (medium category). All three creativity indicators showed greater improvement in the experimental class compared to the control class.

This study's external validity is limited by its single-institution context and sample size (51 pre-service physics teachers; 29 experimental, 22 control). Although we employed validated instruments (Aiken's $V \geq 0.81$), pre–post comparisons against a control group, assumption checks, and reported both effect size ($d = 0.38$, medium) and N-gain (experimental 0.38 vs control 0.06), these design features do not fully overcome constraints on generalizability. Accordingly, future research will extend to multi-institution cohorts, apply stratified sampling across programs/regions, and conduct replication studies to test ecological validity in varied curricular settings.

Future research is recommended to incorporate structured reflection features into the AppYet e-module, such as reflective question guides or experience evaluation templates, to optimize the experience evaluation phase, which currently shows relatively low implementation. The TBP-DIFLAE model holds strong potential to be adapted to other learning contexts and is recommended for further testing on a broader scale or across different courses, in order to gain a more comprehensive picture of its effectiveness and to strengthen the model design for enhancing 21st-century skills, particularly creativity in teacher education.

Implications and recommendations for teacher educators: To facilitate adoption at scale, we recommend (1) curriculum integration—embed TBP-DIFLAE as an eight-session project strand mapped to course learning outcomes and aligned with the Merdeka Curriculum's flexibility for differentiated, in-depth concept exploration; use our validated instruments and creativity indicators to ensure constructive alignment; (2) faculty capacity building—offer short workshops on AppYet e-module authoring (content, layout, offline-access options) and rubric calibration for creativity assessment, paired with implementation checklists to maintain the high practicality observed in this study; (3) blended-learning scale-up—roll out TBP-DIFLAE in blended formats that combine studio-style project meetings with AppYet-based asynchronous tasks, adopting the same eight-session pacing used here to preserve fidelity while allowing cross-course replication; and (4) quality assurance—use the validated toolset and scoring procedures from this study for monitoring (Aiken's V = 0.78–0.94; implementation ≈ 86%; medium effects) and document lesson-level adjustments for continuous improvement.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The study was conceptualized and reviewed by Rajo

Hasim Lubis, who also supervised data extraction, drafted the manuscript, and assisted with result interpretation. Derlina and Ida Wahyuni contributed to conceptualization, conducted statistical analyses, assisted with data extraction, and co-wrote the manuscript. Deo Demonta Panggabean and Yanthy L. P. Simanjuntak facilitated manuscript revision and led result interpretation. Deo Demonta Panggabean conducted final editing of the article, while Yanthy L. P. Simanjuntak contributed to statistical analyses and data extraction. All authors reviewed and approved the final manuscript.

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