Design and Validation of Multimodal Project-Based Learning Syntax for Prospective Physics Teachers

Gunawan[1]*, Ahmad Harjono[1], Muhammad Zuhdi[1], Jannatin Ardhuha[1], Nina Nisrina[1], Windy Zaerani[1], & Shelliana Iqlima[1]
[1]Department of Physics Education, University of Mataram, Indonesia
*Corresponding Author: gunawan@unram.ac.id

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***Abstract** - Physics education in the digital era demands pre-service teachers to be proficient in packaging abstract concepts into cognitive-friendly, multimodal digital media. However, conventional Project-Based Learning (PjBL) models frequently remain final product-oriented, lacking explicit guidance on content representation. This study aims to describe the conceptual design process of the Multimodal-PjBL syntax for pre-service physics teachers and to evaluate its theoretical feasibility. The research adopted a Research and Development (R&D) approach using the ADDIE model, which was limited to the first three phases up to expert validation. Data were collected utilizing a 5-point Likert scale expert validation instrument evaluating content accuracy, structural construct, readability (language), and technical presentation of the Model Book, instructional kits, and supporting research instruments. The research subjects involved four expert validators (two content specialists and two media specialists). Quantitative data were analyzed using a five-point mean score conversion interval, while qualitative data were processed interactively through data reduction and a revision tracking matrix. The results revealed that the structural modification of the PjBL syntax was successfully and logically integrated with multimodal aspects across all instructional stages. Quantitatively, all developed documents achieved a "Highly Valid" predicate, with mean scores consistently ranging from $4.50 \leq M \leq 5.00$. Notably, the digital product assessment instrument and the textbook achieved a perfect score of 5.00. Qualitatively, the initial draft was refined based on expert feedback through high-resolution vector graphic enhancements, the elimination of double-barreled statements, and the formulation of operational descriptors to minimize inter-rater bias. In conclusion, the Multimodal-PjBL syntax is proven to satisfy rigorous content and construct validity principles, making it highly feasible as an instructional foundation for digital science media production courses.*

***Keywords:** Multimodal-PjBL Syntax, Pre-service Physics Teachers, Expert Validation, Instructional Design, Digital Media*

INTRODUCTION

Physics education in the digital era faces massive transformational challenges, where the integration of artificial intelligence (AI) and digital media has redefined the landscape of educator professionalism (Gunawan et al., 2026a). As the vanguard of classroom innovation, pre-service physics teachers are no longer merely required to master theoretical pedagogical content. They must possess the practical ability to package abstract physics concepts into varied and adaptive digital visualizations tailored to the needs of the 21st-century generation (Gunawan et al., 2025b). The use of digital technology in science education has been proven to reduce misconceptions while boosting students' intrinsic motivation (Chen & Chang, 2024; Wang & Reeves, 2020). Therefore, equipping prospective teachers with the competence to produce interactive digital media has become a crucial agenda in teacher preparation programs (Chen et al., 2020; Gunawan et al., 2026a).

One instructional strategy considered effective for training 21st-century skills and media production proficiency is Project-Based Learning (PjBL) (Fadhilah & Thahir, 2023; Prajoko et al., 2023). Through PjBL, students can explore the creation of various digital artifacts to explain physics phenomena (Wang, 2020). However, the implementation of conventional PjBL in higher education often falls into a 'final product-oriented' trap, failing to provide explicit instructional guidance regarding content representation (Gunawan et al., 2025a). Consequently, the digital media produced by pre-service teachers often lacks semiotic depth, merely transferring textbook content into a digital format without proportionally aligning visual, audio, textual, and animated elements. Thus far, multimodal literacy has been viewed as distinct from the PjBL framework, leaving a theoretical and practical gap regarding how an instructional syntax can systematically integrate the multimodal design process from the planning stage to media production (Gunawan et al., 2025b). Yet, the clarity of multimodal representation heavily determines the effectiveness of delivering physics concepts to students (Amrullah et al., 2026a, 2026b).

To bridge this gap, a breakthrough is needed in the form of developing a PjBL syntax structured around a multimodal approach. This Multimodal-PjBL syntax is designed to guide students not only through project time management but also toward sharp science communication through diverse semiotic modes (Gunawan et al., 2025a; Qothrunnada et al., 2025). In the proposed model, students receive rigorous methodological interventions at every phase of the project. They are taught how to deconstruct abstract physics content, design multimedia storyboards, select and synchronize accurate audio-visual assets, and execute the production of a cognitively friendly final product. This integrated step-by-step structure is expected to minimize students' 'cognitive load' while maximizing their creative exploration space in digital visualization (Gunawan et al., 2026b; Lin & Wu, 2016).

The 'novelty' of this study lies in the structural modification of the PjBL syntax, which explicitly adopts multimodal representation principles at each stage of learning, an aspect not specifically addressed in standard PjBL or conventional hybrid models (Gunawan et al., 2025a; Prajoko et al., 2023). While previous studies have tended to focus on utilizing instant platforms like Canva or static e-modules (Fadhilah & Thahir, 2023; Zakiyah, 2024), this study offers a 'procedural framework' for lecturers to manage accountable multimedia project-based courses.

Based on this urgency, this article specifically aims to describe the conceptual design process of the Multimodal Project-Based Learning syntax for pre-service physics teachers, as well as to test its feasibility based on expert validity. The findings of this study are expected to serve as a solid instructional foundation for policymakers in teacher education institutions (LPTK) to produce future teachers who are responsive to the dynamics of digital technology.

RESEARCH METHODS

This research and development (R&D) study adopts the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design model (Branch & Varank, 2009). However, aligned with the scope of this article, which emphasizes conceptualization and theoretical feasibility testing, the research procedures are strictly limited to the first three phases: analysis, design, and development up to the expert validation stage.

1. The analysis phase involves analyzing science curriculum needs and exploring the theoretical integration of Project-Based

Learning (PjBL) syntax with multimodal aspects (text, audio, visual, and kinesthetic) (Gunawan et al., 2025a).

2. Based on the analysis results, the design phase entails drafting the initial prototype (Prototype I), which comprises the Model Book, instructional kits, and all supporting research instruments.
3. Subsequently, in the development phase, this initial draft is evaluated to test its theoretical feasibility.

The subjects involved in this study are specifically restricted to expert evaluators, consisting of four validators tasked with assessing the content and construct validity of the syntax and its supporting kits before they are declared feasible for field testing in subsequent research.

1. Data Collection Instruments

Research data to test theoretical feasibility were collected using expert judgment validation sheets (Creswell & Creswell, 2017). The expert validation sheet is designed using a 1–5 Likert scale to measure the feasibility of the syntax components, instructional kits, and their supporting research instruments. This evaluation instrument specifically measures four core dimensions: content accuracy, structural construct, readability, and technical presentation. In addition to quantitative assessment, the validation sheet is equipped with a qualitative notes section specifically intended to gather comments, critiques, and suggestions for improvement from the experts, while also serving as an instrument to track the chronology and revision record of the draft model design during the development phase.

2. Data Analysis Techniques

The data analysis technique combines descriptive quantitative and qualitative analysis approaches to provide an objective conclusion regarding the model's theoretical feasibility. Quantitative data obtained from the expert validation sheet scores are analyzed by calculating the mean score for each component of the assessment aspects. The mathematical formula used to calculate the mean score is as follows:

$$M = \frac{\sum X}{n} \quad (1)$$

which M is the final mean score, sum of X ($\sum X$) is the total score assigned by all validators, and n is the number of evaluating validators.

Table 1. Five-Point Likert Scale Conversion Criteria for Theoretical Validity

No.	Mean Score Interval (M)	Validity Category	Description / Instructional Action
1	4.21 ≤ M ≤ 5.00	Highly Valid	Highly feasible for instructional use without revision
2	3.41 ≤ M ≤ 4.20	Valid	Feasible for instructional use with minor revisions
3	2.61 ≤ M ≤ 3.40	Moderately Valid	Moderately feasible, requiring substantial structural revisions
4	1.81 ≤ M ≤ 2.60	Invalid	Poorly feasible, requiring total conceptual reconstruction
5	1.00 ≤ M ≤ 1.80	Highly Invalid	Completely unfeasible and rejected for research implementation

The final mean scores obtained from the expert evaluation were analyzed descriptively to determine the level of theoretical validity of the developed products. The score conversion guidelines based on a five-point Likert interval scale are detailed in Table 1. The proposed syntax, instructional kits, and supporting research instruments were deemed to have met the rigorous standards of theoretical accountability if the final mean score achieved a minimum threshold of the 'Valid' category (M greater than 3.41).

RESULTS AND DISCUSSION

Results

1. Design of the Multimodal Project-Based Learning Syntax

The primary product of this prototyping stage is the initial draft (Prototype I), which features a structural modification of the conventional Project-Based Learning (PjBL) syntax. This modification was carried out by explicitly integrating multimodal literacy into each instructional stage. This integration aims to provide a procedural guide for pre-service physics teachers in deconstructing abstract physics concepts and packaging them into cognitively friendly digital representations (text, audio, visual, and kinesthetic). The logical relationship among the standard PjBL stages, the forms of multimodal intervention, and the visualization of concrete activities of pre-service physics teachers is presented in the comparative matrix in Table 2.

Table 2. Comparative Matrix of Standard PjBL Syntax and Multimodal Intervention in Pre-Service Physics Teacher Education Courses

No	PjBL Standard Sintax	Multimodal Aspect	Activity of Pre-Service Teacher Student
1	**Start with the Essential Question**	**Visual & Audio Modes:** Providing stimuli of abstract physics phenomena through mode-rich videos/simulations.	• Students observe digital demonstrations of physics phenomena. • Students identify representational gaps in existing school media and formulate science communication problems to be resolved through the project.
2	**Design a Plan for the Project**	**Text & Visual Modes:** Transforming scientific ideas from conceptual text into pictorial designs (storyboards).	• Students collaboratively draft narrative scripts (Text Mode) and design multimedia storyboards (Visual Mode). • Students map out the required assets (images, animations, explanatory text, sound effects) needed to reduce physics misconceptions.
3	**Create a Schedule**	**Text & Action Modes:** Organizing production tasks based on the technical characteristics of each medium.	• Students construct a specific digital media production timeline (voiceover recording schedule, animation creation schedule, and video editing schedule).
4	**Monitor the Students and the Progress of the Project**	**Audio, Visual, & Gestural Modes:** Providing formative feedback on early drafts of digital media.	• Students present rough drafts of their digital media (testing audio-visual synchronization). • Students perform revisions based on peer reviews regarding standard text clarity and the alignment of voice narration with physics formula visualizations.
5	**Assess the Outcome**	**Integrative Multimodal Mode:** Disseminating final digital artifacts that fully combine all semiotic modes.	• Students explore and present the final digital media products (e.g., interactive e-modules or AI-based explanatory videos). • Students demonstrate how the combination of text, audio, and

No	PjBL Standard Sintax	Multimodal Aspect	Activity of Pre-Service Teacher Student
			visuals in their work can facilitate students' understanding of physics concepts.
6	**Evaluate the Experience**	**Text & Verbal Modes:** Metacognitive reflection on cognitive load and the effectiveness of science communication.	• Students write reflective journals regarding technical barriers encountered in integrating various communication modes. • Students evaluate changes in their self-efficacy concerning Technological Pedagogical Content Knowledge (TPACK) mastery.

2. Expert Validation Results for Learning Tools and Research Instruments

Following the formulation of the operational draft for the Multimodal Project-Based Learning syntax, the next crucial step was to evaluate its theoretical feasibility through expert judgment. The quantitative evaluation results from the validators regarding the feasibility of the developed learning tools and research instruments are detailed in Table 3. This assessment measures four primary dimensions: content accuracy, structural construct, readability, and technical presentation.

Table 3. Average Validation Score per Aspect

No	Validated Documents	Average Validation Score per Aspect				Average
		Content accuracy	Structural construct	Readability (language)	Technical presentation	
1	Creativity Test Instrument	5.00	4.80	4.90	4.50	4.80
2	Creative Process Assessment Instrument	4.90	4.75	5.00	5.00	4.91
3	Digital Product Assessment Instrument	5.00	5.00	5.00	5.00	5.00
4	Textbook and Instructional Kits	5.00	5.00	5.00	5.00	5.00
5	Student Response Questionnaire Instrument	4.90	4.80	4.70	4.70	4.78

Based on the data in Table 3, all developed documents obtained remarkably high mean scores, ranging from 4.50 to 5.00. Specifically, the Digital Product Assessment Instrument and the Textbook and Instructional Kits successfully achieved perfect scores (5.00) across all evaluation aspects. These high scores indicate that the developed products integrating a multimodal approach have satisfied the principles of robust content and construct validity, possess straightforward linguistic readability, and exhibit excellent technical readiness, rendering them highly suitable for operational field testing in the classroom.

3. Results of Qualitative Evaluation (Revision Record Table)

In addition to providing quantitative scores, the validators also offered qualitative feedback in the form of critiques, comments, and suggestions for improvement. This qualitative data was analyzed interactively to reconstruct and finalize all instructional documents. The track record of design changes from Prototype I to the final product is presented in Table 4.

Table 4. Qualitative Revision Track Record from Expert Validators

No	Validated Document	Evaluation Aspect	Validator Comments / Critiques	Corrective Actions / Design Revisions
1	**Creativity Test Instrument** (Lowest Technical Score: 4.50)	Technical Presentation	• The time allocation for completing the test is too constrained and has not been explicitly stated on the instrument sheet. • The graphical or diagrammatic quality of physics phenomena in the creative thinking test items is blurry, and the scales are disproportionate.	• Adding rational duration guidelines for completion (e.g., 20 minutes per divergent test item). • Replacing all physics diagrams and graphs with high-resolution vector formats to ensure clear visual readability.
		Structural Construct	• Divergent reasoning indicators still overlap between the flexibility and originality aspects.	• Restructuring the question prompts to specifically trigger a single, measurable creativity indicator.
2	**Creative Process Assessment Instrument** (Lowest Construct Score: 4.75)	Structural Construct	• The descriptors in the process assessment rubric are too abstract, potentially leading to inter-rater bias when observing group work.	• Modifying abstract verbs into operational, directly observable behavioral indicators (e.g., "students actively discuss the audio-visual layout on the storyboard").
		Content Accuracy	• Assessment during the monitoring phase does not yet strictly measure how students convert physics concepts into visual modes.	• Adding a specific assessment item regarding the precision of semiotic representation selection (alignment between graphics and explanatory text).
3	**Digital Product Assessment Instrument** (Perfect Score: 5.00)	Technical & Language (Minor Refinements)	• The assessment sheet is highly comprehensive; however, the rubric numbering format across the lecturer, self, and peer assessment sheets needs to be standardized to avoid confusion.	• Standardizing the layout, font size, and instrument code numbering for the self-assessment, peer-assessment, and expert-assessment versions.
4	**Textbook and Instructional Kits** (Perfect Score: 5.00)	Content & Presentation (Minor Refinements)	• The designed Multimodal-PjBL syntax is highly coherent; however, the transition boundaries between modes (when students read text versus when they must produce a video) need to be explicitly reinforced in the text.	• Incorporating bold text, flowcharts, and specific visual icons in the Model Book to mark shifts in communication modes within the instructional syntax.
		Readability (Language)	• There are several double-barreled statements that confuse students (e.g., "This	• Splitting double-barreled statements into single, focused items (one item assessing the

No	Validated Document	Evaluation Aspect	Validator Comments / Critiques	Corrective Actions / Design Revisions
5	**Student Response Questionnaire Instrument** (Lowest Language & Technical Score: 4.70)		syntax is easy to understand and catches my attention").	ease of understanding instructions, and another assessing visual appeal).
		Technical Presentation	• The layout design for response options (Likert Scale) is horizontally too dense, risking response errors by participants.	• Adjusting the layout of response choices with wider spacing for better readability and comfort.

Based on the revision records in Table 4, the refinement process of the model draft focused on strengthening instructional clarity, eliminating bias in process assessment instruments, and optimizing the visual quality of science visualizations. All validator comments were fully accommodated during the development stage. These revisions resulted in the final product of Prototype I, which is theoretically valid based on quantitative accuracy and possesses mature practical accountability due to the structural and linguistic refinements suggested by the experts.

Discussion

1. Theorization and Conceptualization of PjBL-Multimodal Syntax

The reconceptualization of the instructional structure by merging conventional Project-Based Learning (PjBL) with a multimodal approach is driven by an urgent need to address fundamental weaknesses in traditional science learning. In standard PjBL, the project implementation process often falls into a final product-oriented trap without providing explicit cognitive guidance to students on how scientific messages should be effectively represented (Fadhilah & Thahir, 2023; Gunawan et al., 2025a; Prajoko et al., 2023). This weakness frequently causes student-generated digital media to suffer from cognitive overload due to unsynchronized visual, textual, and audio elements (Mayer, 2021; Sweller et al., 2011). By integrating multimodal literacy declaratively into each stage of the syntax, this draft model successfully formulates a procedural framework that requires pre-service physics teachers to consciously engage in semiotic translation. This new framework ensures that digital project execution is not merely a pure software technical activity but rather a process of conceptual reconstruction of science that is friendly to the human information processing system (Gunawan et al., 2025b; Kress, 2010).

Through an in-depth analysis of the syntax comparison matrix, it is evident that multimodal intervention transforms the role of pre-service teachers from mere consumers of technology into adaptive instructional multimedia designers. When students are prompted to transform abstract conceptual ideas from textbook formats into pictorial designs (storyboards), they simultaneously hone their visual and spatial literacy skills (Jewitt, 2008; Lestari et al., 2018; Wang, 2020). The process of mapping digital assets—such as images, animations, voice narrations, and sound effects—forces the deconstruction of complex physics content. Consequently, students indirectly deepen their mastery of essential material through directed collaborative work while structurally minimizing the potential for physics misconceptions (Amrullah et al., 2026a; Gunawan et al., 2025a, 2025b).

In the final stages of the syntax, the designed model provides a structured space for formative evaluation and students' metacognitive reflection. Implementing peer reviews on digital media drafts serves as an effective quality control instrument to minimize linguistic technical errors and audio-visual misalignments prior to final product dissemination (Benlaghrissi & Ouahidi, 2024; Qothrunnada et al., 2025). Furthermore, compiling reflective journals at the end of the course trains students' metacognitive abilities to evaluate technical barriers and measure fluctuations in their self-efficacy while combining various semiotic modes (Lin & Wu, 2016; Wang & Reeves, 2020). The integration of contemporary technology, including the utilization of artificial intelligence (AI) in physics digital media production, has also been proven to increase intrinsic motivation while accelerating the acquisition of 21st-century skills required by professional prospective educators (Chen & Chang, 2024; Gunawan et al., 2026a; Lee & Chung, 2024).

2. Quantitative Analysis of Instrument Feasibility (Expert Validity)

The successful conceptualization of this Multimodal-PjBL syntax is empirically supported by quantitative validation data, where all developed documents obtained exceptionally high mean scores ranging from 4.50 to 5.00. Specifically, achieving a perfect score (5.00) for the Digital Product Assessment Instrument and the Textbook and Instructional Kits demonstrates absolute alignment between the theoretical foundations of the model and practical needs in higher education courses. This high content and construct validity guarantees that the developed learning tools possess robust theoretical accountability and are ready for use as reliable research instruments in the subsequent implementation phase.

The high scores achieved in content accuracy and structural construct dimensions reflect the precision of instrument design within the context of modern physics education. As a discipline dense with abstract concepts, physics requires evaluation instruments that go beyond measuring lower-order cognitive skills to objectively trigger and measure the creative thinking skills of prospective teachers (Amrullah et al., 2026b; Chiu & Hwang, 2024). The assessment rubrics designed in these tools are guaranteed to accurately record students' divergent thinking indicators, such as fluency, flexibility, originality, and elaboration, through the concrete activity of digital media production. Aligning scientific conceptual precision with instructional multimedia design serves as a primary key for Teacher Education Institutions (LPTK) to produce graduates who not only master theory but are also proficient in visually communicating science to students (Chen et al., 2020; Lin et al., 2024; Zakiyah, 2024).

3. Qualitative Revision Track Record and Design Refinement

Although quantitative results indicated remarkably high scores, the qualitative evaluation via the revision track record table demonstrates a transparent and accountable process of model refinement. Critiques from the validators regarding the technical presentation of the Creativity Test Instrument—such as blurry physics diagrams—were immediately addressed through vector-based reconstructions and the restructuring of question prompts to specifically trigger a single, measurable creativity indicator. This corrective action was crucial to ensure that the test instrument truly measures students' creative thinking skills rather than testing their ability to decipher unclear images. Standardizing these instrument items minimizes measurement errors and ensures that the evaluation tool remains sensitive to students' creative growth throughout the project implementation.

On the other hand, operational modifications to the process assessment instrument and the student response questionnaire demonstrate the importance of usability and inter-rater bias elimination techniques in classroom evaluation. Changing abstract verbs into observable behavioral indicators helps lecturers provide fair and consistent assessments during the project monitoring phase. Furthermore, splitting double-barreled statements and reorganizing the Likert scale tables are theoretically proven to reduce respondents' reading fatigue, thereby enhancing the validity of students' psychological responses. Meanwhile, the addition of visual markers—such as bolding, flowcharts, and mode transition icons in the Model Book—provides user-friendly navigation for independently internalizing the Multimodal-PjBL syntax (Fadhilah & Thahir, 2023; Gunawan et al., 2025a; Zakiyah, 2024).

4. Implications, Limitations, and Future Directions

Holistically, the finalization of a quantitatively and qualitatively valid Prototype I draft offers a significant theoretical contribution to strengthening the Technological Pedagogical Content Knowledge (TPACK) framework of pre-service physics teachers. Through this refined Multimodal-PjBL syntax, technology mastery is no longer taught in isolation as a purely technical skill but is systemically embedded into the PjBL pedagogical method to deliver physics content accurately (Gunawan et al., 2026b; Mishra & Koehler, 2006). This mature theoretical readiness and instrument set establish a solid foundation for conducting large-scale field testing to examine the operational effectiveness of the model in enhancing real classroom creativity. Consequently, the outputs of this study hold high relevance for adoption by teacher education institutions to address the demands of global science education digitalization (Chen et al., 2020; Gunawan et al., 2026a, 2026b).

Although the Prototype draft of the Multimodal Project-Based Learning syntax has been declared highly valid theoretically by experts, this study is still primarily limited by its scope of testing, which has not yet involved direct empirical implementation in the classroom. The focus of this article is strictly confined to the analysis, design, and instrument development phases through quantitative and qualitative expert validation. Therefore, future work will be specifically directed toward large-scale implementation and evaluation (field testing) to measure the operational practicality of the syntax and its real effectiveness in boosting the creative thinking skills, creative processes, and digital media product quality produced by pre-service physics teachers.

CONCLUSION

This study has successfully designed and structurally formulated a Multimodal Project-Based Learning (Multimodal-PjBL) syntax for pre-service physics teachers. Based on the conceptual evaluation by experts (expert judgment), all drafts of the learning tools and supporting evaluation instruments achieved a 'Highly Valid' status, with conversion mean scores consistently falling within the range of $4.50 \le M \le 5.00$. The instructional implications of these findings are fundamental; this syntax offers a new roadmap for physics lecturers in managing digital media production courses. Through this integrated framework, lecturers can shift their teaching approach from a pure focus on software technical mastery to a systematic guidance process for science communication, where students are trained to deconstruct abstract physics concepts into various semiotic modes (text, audio, visual, and action) that are friendly to learners' cognitive load.

Given that the scope of this article is focused on the conceptualization phase of the Prototype I draft and theoretical feasibility testing, the high validity scores obtained from experts guarantee the legitimacy of this model for testing in real classroom situations. Therefore, the recommendation for future work is to conduct empirical implementation through large-scale field testing. This subsequent research is crucial to test the operational practicality of the model for both lecturers and students, while simultaneously measuring the actual effectiveness of applying this Multimodal-PjBL syntax in boosting critical thinking skills, the originality of the creative process, and the quality of the final digital media products produced by pre-service physics teachers on a larger and more diverse classroom scale.

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