Development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development

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Abstract **– Learning management in the 21st century requires the integration of innovative approaches that stimulate imaginative thinking processes while simultaneously promoting practical, hands-on skills. The findings indicate that integrating the imagineering concept with virtual reality technology is an effective approach for transforming abstract content into concrete learning experiences. This integration helps reduce learning constraints and enhances creative thinking and innovation skills that are essential for learners. This study aims to develop a Virtual Reality-Based Imagineering Project Learning Management Model to enhance creative thinking and innovation skills. Additionally, the study assesses the suitability of the developed model through an evaluation by a total of fifteen experts, including specialists in Education, Electrical Communications, and Information and Communication Technology. The research instrument used in this study was a learning model suitability assessment form. The research findings indicate that the developed instructional model consists of four main components: Input Factors, Learning Process, Assessment, and Feedback.**

The results of the expert evaluation indicated that the developed learning model was rated at the highest level, thereby demonstrating a high degree of suitability and practical readiness for implementation in subsequent empirical trials aimed at enhancing learner development.

Keywords **– Imagineering Project Based Learning, Virtual Reality, creative thinking, innovation skills.**

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1. Introduction

Currently, information and communication technologies have been rapidly advancing and becoming a part of daily lives in terms of industry economy, and education. The three components were a part of Thailand's drive into the 4.0 era that focuses on the use of information and communication technology in place of human labor in the industry and economic sectors and is an age of rapid knowledge construction and destruction, and an age of learning and knowledge integration. In the face of such changes, education will be an important tool that can elevate the Thai people's quality of life in the face of such changes, by reducing the gap between skills obtained from the education system and the industrial and economic sectors. The education system that can adapt to the working environment typical of the 4.0 industrial and economic sectors must be mindful of the change in the learning method, with more emphasis on technical knowledge instead of normal memorization, as well as more emphasis on learning skills and adaptation skill building so the learners can improve themselves. Assessment must move away from the traditional examination-centric approach, and during the transition period, the skills must be elevated, or there must be new training to help the learners adapt to the 4.0 Thailand [1]. Life in the 21st century, in which education serves in the age of knowledge, requires self-development through technology, tools, and application of knowledge into innovation, as well as requires the teachers to have skills in motivating the

learners to enjoy and stay entertained with learning, and pursue lifelong learning based on the principle of "less teaching, more learning."

Consequently, educators should design and facilitate experiential learning environments, employing a variety of pedagogical methods and tools to tailor instruction to the diverse needs of learners [2], [3].

Development of a learning model in the 21st century requires the inclusion of information technology in the model thus, the educators and relevant parties must collaborate in applying technologies in effective education reform, aiming to instill technological competencies in the learners. The teacher can use it as a tool to pass on knowledge and create workpieces for the learner. This is a technological skill integration that becomes relevant to the curriculum and content. One of the notable technologies is Virtual Reality is defined as a user-centric, computer-generated 3D environment that offers an immersive, interactive, and multi-sensory experience, supported by a combination of technologies essential for constructing such environments [4]. This technology simulates a virtual setting perceived through vision, sound, and touch. Typically, it is displayed on computer screens or 3D projectors, where users can interact with the environment using standard devices such as a keyboard or mouse, often creating simulations that closely resemble the real world [5]. This is a new educational media in which the learner becomes interested in the new knowledge and experience, along with interaction and connection with the classroom. VR is a blend of the reality and virtual environment where the learner can participate in the class, compared to the past learning management. Application of technology in the current and future online classes, along with effective learning management, will promote learning in the digital age.

Designing learning management in the current time requires instilling creative thinking and innovation skills, both of which the learners must pay attention to and train themselves constantly in order to attain a high life quality. There must be a promotion of creative thinking, that would lead to diversity, awareness of the relationship between things, and/or development of new innovation [6]. Therefore, creative thinking is related to the initiative, flexibility, nimbleness, and detailed ideas, along with the ability to create novel ideas to find the best answer for existing problems [7]. A novel idea is an innate personal ability that is new and unique and could come from the development of existing ideas into creative thinking and the ability to create useful and creative innovations, which is a desirable trait for learners of the 21st century, and the National Education Act B.E. 2542 [8] that aims for the learners to self-develop.

Nevertheless, creative thinking and innovation rely on project-based learning, which sets up the learning by allowing the learners to work together on their projects of interest. The learners will together survey, observe, set the topic, cooperate on the project, research, and work as planned until a new finding or invention is made [9], [10]. This approach also promotes creative thinking which is a critical skill for learners of the 21st century. This process encourages the learner to seek answers or solutions without being fixed to the traditional framework through brainstorming thinking outside the box, reasonable imagination, and imagineering. The concept of imagineering is a learning management concepts focusing on developing learner traits for the 21st century by focusing on self-learning, creative thinking, and innovation skills. Imagineering consists of six aspects: imagination and topic; planning and designing; development and testing; presentation; improvement; and assessment and conclusion [11]. According to the aspects of imagineering, they emphasize self-learning through bringing imagination into practice, or tangible innovation or inventions. The project-based learning when used in conjunction with imagineering would allow the learner to expand ideas, improve creative thinking, develop creative work, and create new knowledge for innovations.

Due to such background, the author desires to develop a project-based learning model mixed with virtual reality-based imagineering as a method to improve creative thinking and innovation skills in the learner to prepare them for the Thailand 4.0 era, which would focus on the use of virtual reality-based information and communication technology, so the learner can learn for life.

2. Research Objectives

The objectives of this research are:

O1: *Develop a Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development.*

O2: *Assess the developed model of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development.*

3. Literature Review

Drawing upon a review of concepts, theories, and research on project-based learning processes by various educators and organizations, Project-Based Learning is defined as an instructional approach where learners investigate topics of interest through inquiry-driven activities.

It is a learning process in which the learners research their topic and together proceed with the study within an agreed time frame in a systematic manner with a diverse range of sources and close guidance from the teacher in every step, from selecting the topic, planning, setting the steps, and presentation until the goal is achieved. Thus, the project is an activity or workpiece with clear steps and connections to a tangible final product. The learners will feel an achievement as they work by themselves in every step of the holistic learner development approach. Project-Based Learning has five steps: 1) Select the topic/issue; 2) Design the method and select the source; 3) Execute the project; 4) Present the project; 5) Measure and assess the result, as shown in Table 1.

The researcher analyzed and synthesized the aforementioned concepts to identify and select the most appropriate and congruent stages of project-based learning for developing the proposed learning model, as presented in Table 1.

The Project-Based Learning Process can be systematically structured into five core stages, as outlined: (1) Topic Selection and Problem Identification: This initial stage involves learners collaboratively exploring and identifying authentic problems or areas of interest (pain points) that warrant investigation. (2) Project Design and Planning: This stage emphasizes systematic planning, wherein learners translate imaginative ideas into concrete and actionable project plans through the selection of appropriate methods and learning resources. (3) Project Implementation and Creation: Representing the creative construction phase, this stage requires learners to execute the project plan in order to transform conceptual ideas into functional prototypes. (4) Project Presentation and Communication: This stage focuses on the articulation and dissemination of project outcomes, including formal presentations, demonstrations of functionality, and responses to critical feedback. (5) Measurement and Evaluation: As the final stage, this phase entails a comprehensive assessment of project success by evaluating both the learning process and the final product, thereby ensuring alignment with the intended learning objectives.

Table 1. Synthesis of project-based learning process

No.	Steps	Authors									Conclusion
		[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	
1	Grouping and attention drawing	/							/	/	
2	Topic/issue selection	/	/	/	/	/	/	/	/	/	/
3	Planning/designing	/	/	/	/	/	/	/	/	/	/
4	Execution	/	/	/	/	/	/	/	/	/	/
5	Result recording					/					
6	Report writing	/						/			
7	Project presentation	/	/	/	/		/	/	/	/	/
8	Measurement and assessment	/	/	/	/	/	/		/	/	/

Based on a review and analysis of concepts related to learning management processes derived from scholarly literature and research conducted by educators and various organizations, Imagineering-Based Learning is defined as a learning process in which learners apply creativity and imagination to investigate topics of personal interest. Through systematic inquiry and diverse methodological approaches, learners engage in purposeful investigation to achieve predetermined learning objectives under the close guidance of a teacher. The researcher analyzed and synthesized the aforementioned concepts to identify the most appropriate and congruent stages for developing the proposed learning model.

This process entailed examining the frequency and alignment of the stages proposed by various educators. Imagineering can be summarized as shown in Table 2, consisting of seven steps: 1) Imagination which is inspiration and setting the problem; 2) Designing which is developing and planning a practical solution to the problem or imagination in the first step; 3) Development which is the actual execution of the design and plan; 4) Testing of the workpiece or method developed in the previous step; 5) Presentation of the work for feedback and comment, as well as idea exchange; 6) Revision based on the feedback in the previous step; 7) Evaluating the work, as shown in Table 2.

Table 2. Synthesis of imagineering learning process

No.	Steps	Researcher							Conclusion
		[21]	[22]	[23]	[24]	[25]	[26]	[27]	
1	Imagination	/	/	/	/	/	/	/	/
2	Designing	/	/	/	/	/	/	/	/
3	Development	/			/	/	/	/	/
4	Testing			/					/
5	Presentation	/	/		/	/	/	/	/
6	Revision		/	/	/			/	/
7	Evaluation			/		/		/	/

The Imagineering Project Learning Model: Is a systematic learning process developed by the author for the learners to learn through imagination and practical experience, and be encouraged to observe, question, hypothesize, and solve the problems in a reasoned and systematic manner, along with creativity that would allow them to create their own knowledge, analyze the problem, design and solve engineering problems, apply knowledge into building a tangible invention or innovation for later application in daily lives, and improve their own creative thinking and innovation skills through the six steps of Project-Based Imagineering Learning: 1) Imagination and topic setting; 2) Designing and planning; 3) Development and testing; 4) Presentation; 5) Revision and 6) Evaluation and conclusion.

Virtual Reality (VR): Is a combination of Virtual Reality with graphical technologies to create a virtual environment for the users. This is a technology that adds virtual objects into the video records taken by the video camera, webcam, or mobile phone camera frame-by-frame with computer graphic techniques. The user can use Virtual Reality in the online working environment which enables them to instantly interact using virtual reality devices that provide a 360-degree view, such as headsets and gloves.

Creative and innovation skills: Creative and innovation skills are thinking, designing, execution, and control skills to make the innovation development successful and effective and remedy the defects. Innovation means applying new ideas, practices, inventions, or improvements of existing ideas and practices that might be ideas, practices, or inventions to improve the existing things. Such proposals would have to be developed and tested in a systematic way to ensure that they are indeed improvements. Examples of such innovations include educational guidelines, product designs, service practices, technological improvements, technological dissemination, and application of technology to benefit the economy and society.

Innovations consist of 1) Creativity, 2) Novelty, 3) Diverse thought processes, 4) Fineness, suitability, and aesthetics, 5) Creation, 6) Quality and application. Creative skills mean an individual intellectual skill that is limitless and capable of expanding beyond traditional work into novel discoveries by adapting existing ideas or inventing theories and principles. Creative skills consist of (1) Intuition and sensitivity towards the problem, (2) Mental acuity, (3) Flexibility, and (4) Attention to detail.

4. Research Methodology

The research method is divided into two phases per the research objectives.

The first phase covered the development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development. Figure 1 shows the research framework by analyzing and synthesizing the basic information of the components, such as project-based learning, imagineering, and Virtual Reality. The key components of the virtual reality system include software that controls the process by receiving images from a camera. The system then processes the digital data and displays the results superimposed onto the real world via a display. Then, the components are taken to delimit the model framework, consisting of four components: (1) Input, (2) Process, (3) Output, and (4) Feedback.

The second phase is an assessment of the Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development by a total of fifteen experts, comprising five specialists each in Education, Electrical Communications, and Information and Communication Technology.

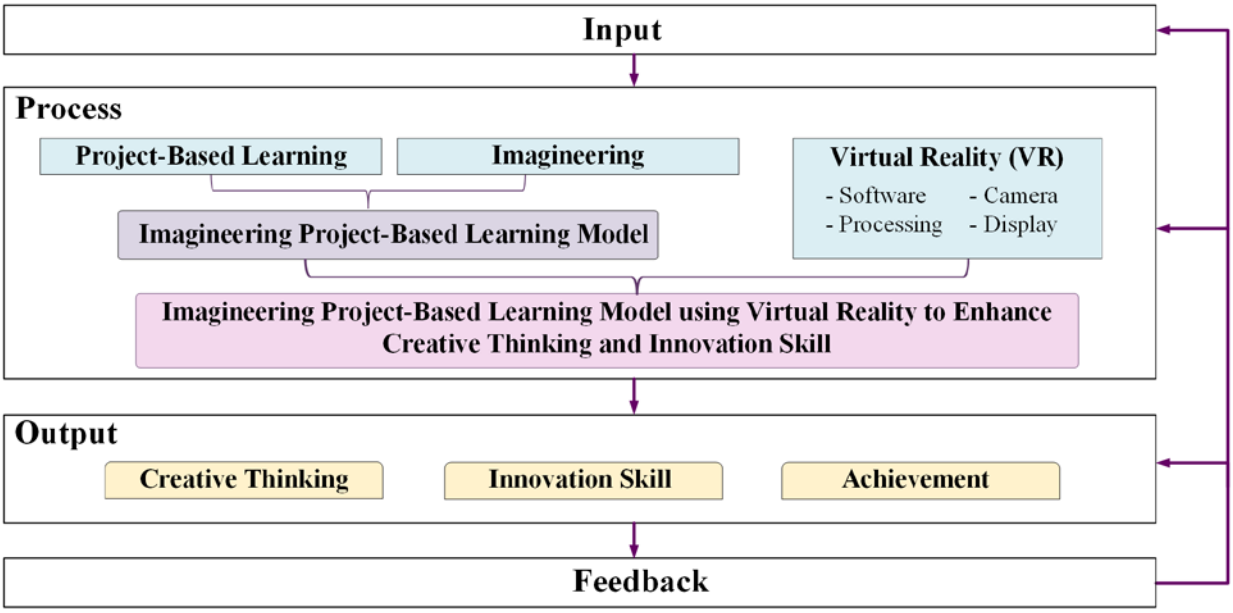

Figure 1. Research framework

5. Results

Result of the Development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development.

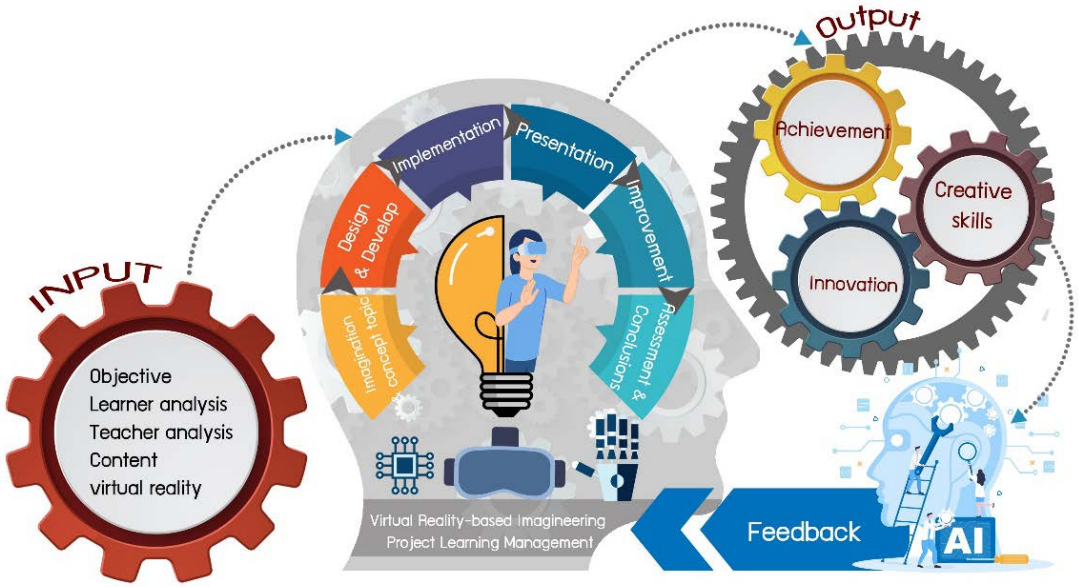

Figure 2. Model of development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development

The Development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development, as shown in Figure 2, used various techniques blending together, and took information obtained from the study, analysis and synthesis of basic information for each component.

The learning process was based on Project-Based Learning Approach and Imagineering as the framework for model development. The author used the system approach with four main components:

1. Define the input factors with five subfactors: (1) Learning objective, (2) Learner analysis, (3) Teacher analysis, (4) Content and (5) Virtual Reality.
2. The Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development has six steps: (1) Imagination and topic setting, (2) Planning and designing, (3) Development and testing, (4) Presentation, (5) Revision, and (6) Assessment and conclusion.
3. Product assessment consists of (1) Creative thinking skills assessment, (2) Innovation assessment and (3) Learning achievement assessment.
4. Product feedback, consisting of creative thinking skill assessment result and innovation assessment result, which can be explained below:

The factors that are necessary input factors in the Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development are the learning objective, learner analysis, teacher analysis, content and Virtual Reality, each in turn has the following subfactors:

Input factors:

1. Objective or the learning behavior setting as expected by the teacher upon conclusion of the Virtual Reality-Based Learning by measuring and evaluating if the learner achieves the following goals: The learner can set the topic and identify the problem. The learner can plan and design the work. The learner can design an engineering project. The learner can improve creative thinking skills and the learner can create innovations.
2. Learner analysis, which is highly important to allow the learner to effectively use the VR technology as appropriate for their capabilities. The learners should be bachelor undergraduates in the engineering field with basic knowledge in electrical measurement and tools, electrical engineering, electronic engineering, information and communication engineering.
3. Teacher analysis, in order to effectively use the Virtual/Augmented reality lab, the teacher must provide guidance in case of problems. The teacher should already be teaching in undergraduate engineering, electrical engineering, electronic engineering, telecommunications engineering, information and communication engineering, and other related fields. The teacher must be well-versed in computer and information and communication technology.
4. Content: This study focuses on operational content from the Information and Communication Engineering Project 3 (0-9-0), following the amended standards [28], the general research and developmental research regulation, the information and communication engineering tool research and development regulation, using technologies appropriate for the local society, economy and environment for sustainability and self-dependence of the community and society. The content is approved by the project advisor and committee.
5. Virtual Reality Technology: It is a computer program created for students to study and review basic electronic engineering knowledge for project work. Contains analysis of electrical and electronic circuits, digital circuit analysis, and programming to control various devices. Students can practice as if they were hands-on with actual experimental equipment. The program also displays media in video format for a review of how to use various features of electrical measuring instruments.

Process:

1. Imagination and concept topic is about building inspiration, setting the question and problem for development and presentation of the project. Thus, this step is applying the idea into a design and planning for eventual actualization.
2. Designing is developing the imagination into a practical plan. The learner will design on how to make the workpiece and obtain necessary information using virtual reality technology.
3. Implementation is creating work as designed and planned, testing the workpiece, and working on any problems. The learners can likewise use virtual reality technology in this step.
4. Presentation covers the presentation and publishing to seek feedback and ideas.
5. Improvement: In this step, feedback from the experts is used to improve the work. This process involves synthesizing critiques and recommendations to revise and refine the content, aiming to correct deficiencies and enhance overall quality to ensure the final output is comprehensive and highly suitable for its intended purpose.
6. The output of the Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development is assessed using authentic assessment approaches to measure creative thinking and innovation skills.

Output assessment:

1. Creative thinking skill is individual intellectual skill that is limitless and capable of expanding beyond the traditional work into novel discoveries by adapting existing ideas, or inventing theories and principles with effective development and revision efforts. Assessment in this part is done based on the report submitted by the learners.
2. Innovation is an assessment of the completed work that is novel, fine-detailed, and usable.

Feedback:

Feedback is taking information from the assessment and learning process, such as the creative thinking and innovation skills for analysis and improvement of the learning process. Then, the input is adjusted to be appropriate for each step to achieve the learning objectives of the Development of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development. The assessment results indicate that the Virtual Reality-Based Imagineering Project Learning Management Model is effective in developing creative thinking and innovation skills.

The assessment results for the Virtual Reality-Based Imagineering Project Learning Management Model for Creative Thinking and Innovation Skills Development were derived from a panel of 15 experts. The panel was comprised of three groups of equal size, consisting of experts specializing in education, electrical communications engineering, and information and communication technology. Overall, the model demonstrated suitability at the highest level (Mean = 4.60, S.D. = 0.49). When examined by individual stages, the evaluation results indicated that the principles and conceptual framework used as the foundation for the learning model design were rated at the highest level of suitability (Mean = 4.80, S.D. = 0.41). This outcome is attributed to the model design prioritizing theoretical accuracy and congruence, ensuring that the foundational structure was sufficiently robust to support the development of creative thinking and innovation skills. Furthermore, the evaluation results regarding the components of the learning model indicated suitability at the highest level (Mean = 4.55, S.D. = 0.50). The model encompassed all key components of general instructional models, reflecting comprehensive coverage as detailed in Table 3.

Table 3. Assessment result for the model of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development

Assessed Items		Result		
		Mean	**S.D.**	**Suitability**
1. Concept and Principle used in the model design		4.80	0.41	Highest
2. Model components **Coverage of the main components of general learning models				
	2.1 Input factors	4.47	0.52	High
	2.2 Learning process	4.73	0.46	Highest
	2.3 Assessment	4.53	0.52	Highest
	2.4 Feedback	4.47	0.52	Highest
	Total	4.55	0.50	Highest
Overall model suitability		4.60	0.49	Highest

The findings regarding the detailed components of the Virtual Reality-Based Imagineering Project Learning Management Model for Creative Thinking and Innovation Skills Development were derived from a panel of 15 experts. The panel comprised three equally sized groups, each consisting of five experts specializing in education, electrical communications engineering, and information and communication technology, respectively. Overall, the model demonstrated suitability at the highest level (Mean = 4.61, S.D. = 0.57). When examined at the item level, the input determination stage was rated at the highest level of suitability (Mean = 4.61, S.D. = 0.54), as it involved a comprehensive analysis of learners' readiness and the implementation of virtual reality technology.

Similarly, the learning process stage was also evaluated at the highest level of suitability (Mean = 4.78, S.D. = 0.42). This stage emphasized the integration of the imagineering concept to foster innovation and promote creative thinking skills. In contrast, the assessment and the feedback were rated at a high level of suitability, with results of (Mean = 4.30, S.D. = 0.65) and (Mean = 4.40, S.D. = 0.86), respectively. This consistency aligns with the research objectives and contributes to ensuring systemic coherence across the entire learning model, as shown in Table 4.

Table 4. Details of the model of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development

Assessed Items		Result		
		Mean	**S.D.**	**Suitability**
1. Input				
	1.1 Learning objective	4.73	0.46	Highest
	1.2 Learner analysis	4.47	0.64	High
	1.3 Teacher analysis	4.53	0.64	Highest
	1.4 Content	4.60	0.51	Highest
	1.5 Virtual reality technology	4.73	0.46	Highest
Total		4.61	0.54	Highest
2. Learning process				
	2.1 Imagination and topic	4.73	0.46	Highest
	2.2 Planning and design	4.80	0.41	Highest
	2.3 Development and testing	4.67	0.49	Highest
	2.4 Presentation	4.67	0.49	Highest
	2.5 Revision	4.87	0.35	Highest
	2.6 Assessment and conclusion	4.93	0.26	Highest
Total		4.78	0.42	Highest
3. Assessment				
	3.1 Creative thinking	4.27	0.70	High
	3.2 Innovation	4.33	0.62	High
Total		4.30	0.65	High
4. Feedback				
	4.1 Creative thinking assessment	4.33	0.90	High
	4.2 Innovation assessment	4.47	0.83	High
Total		4.40	0.86	High
Overall		4.61	0.57	Highest

The findings regarding the suitability of the Virtual Reality-Based Imagineering Project Learning Model for enhancing creative thinking and innovation skills were derived from a panel of 15 experts. The panel comprised three equally sized groups, each consisting of five experts specializing in education, electrical communications engineering, and information and communication technology, respectively. Overall, the model demonstrated suitability at the highest level (Mean = 4.53, S.D. = 0.50).

When examined at the item level, both the suitability for developing creative thinking and innovation skills and the procedures and activities of the learning model demonstrated suitability at the highest level, sharing the highest mean score (Mean = 4.60, S.D. = 0.51). The next highest aspect was the feasibility of practical implementation, which demonstrated suitability at a high level (Mean = 4.40, S.D. = 0.51). These findings demonstrate that the developed model is well prepared in terms of both theoretical foundations and procedural design for practical application in enhancing learner development, as shown in Table 5.

Table 5. The model of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development

Assessed Items	Result		
	Mean	**S.D.**	**Suitability**
1. Appropriateness of the Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development	4.60	0.51	Highest
2. Steps and activities of the Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development	4.60	0.51	Highest
3. Feasibility of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development	4.40	0.51	High
Total	4.53	0.50	Highest

6. Discussion

This section outlines the components of the instructional model for Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills. The development of this model relies on the interconnectedness of its various components. The instructional process incorporates learning activities designed to allow learners to practice creative thinking and innovation skills. Learners can study independently. The model emphasizes hands-on practice and project presentation to cultivate skills in thinking, design, implementation, and the efficient control of various systems, ultimately leading to successful innovation development.

Furthermore, learners can enhance their language usage, presentation skills, and the proper application of information technology as they are required to summarize learning outcomes at each stage, thereby synthesizing knowledge applicable to their projects. Upon completing all instructional activities, an evaluation of the products resulting from the learning process is conducted. Specifically, this research focuses on assessing creative thinking and innovation skills. After the conclusion of all processes, feedback from both instructors and learners is directed back to the input and instructional process stages to enhance and optimize the model.

The development of this instructional model is based on the systematic approach, comprising four key components: input, process, output, and feedback. This aligns with [29], who stated that a systematic approach is essential for quality instruction, enabling learners to achieve defined objectives effectively. This is further supported by [30], who noted that organizing learning activities systematically ensures efficient instructional processes and verifiable achievement, and by [31], who asserted that a systematic instructional design guarantees effective learning outcomes.

However, educational personnel intending to implement this developed learning model must ensure preparedness regarding its core elements, namely: instructors, learners, virtual reality technology, learning resources, the learning environment, and course content. Each element should possess the characteristics specified by the researcher, with particular attention given to the adequacy of digital devices and internet connectivity.

7. Conclusion

From the study on the model of Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development, topics for this part can be identified as follows:

The proposed model is based on the concepts, principles, and theories of project-based learning, imagineering, and virtual reality technology. The concepts and theories are analyzed and synthesized to create a learning activity guideline, with a focus on creative thinking and innovation skill building. This leads to the components, steps, and objectives of the learning model, which are used for model development: 1. Input factors with five subcomponents: (1) Learning objective; (2) Learner analysis; (3) Teacher analysis; (4) Content and (5) Virtual reality technology; 2. Virtual Reality-Based Imagineering Project Learning Management for Creative Thinking and Innovation Skills Development consisted of six parts: (1) Imagination and topic; (2) Planning and designing (3) Development and testing (4) Presentation (5) Improvement and (6) Assessment and conclusion. 3. Product assessment with three parts: (1) Creative thinking skills assessment; (2) Innovation assessment; (3) Learning achievement assessment; and 4. Product feedback consists of creative thinking skill assessment, innovation assessment, and model suitability assessment.

The research findings indicate that the components related to the input factors and the learning process were assessed at the highest level of suitability. This outcome reflects the systematic design of the model, where content and learning activities were logically sequenced and coherently interconnected. Additionally, the selection of virtual reality technology demonstrated a precise alignment with learners' capabilities and the specific nature of the subject matter.

Regarding the evaluation components, the findings indicate that the assessment and feedback were rated at a high level. This is attributed to the fact that evaluating creative thinking and innovation skills requires authentic assessment approaches that emphasize performance-based competencies. Consequently, the assessment criteria must be flexible and designed to simultaneously consider both the learning process and the final product. Therefore, the implementation of rubric-based assessment is essential, serving as an effective tool for translating abstract constructs into clear and tangible performance criteria.

Concerning the suitability assessment of the model, the fifteen experts, divided into three groups (education, electrical and communication engineering, and information and communication engineering), of five experts each, assessed the model. The experts unanimously agreed that the model was consistent with the principle and idea in model development, and had the goal of developing creative thinking and innovation skills that concurred with the principle of the model, learning management process, and assessment. Thus, the model was given the "highest" level of suitability score.

As the developed instructional model is grounded in systematic instructional design principles with clearly articulated stages, it significantly fosters the enhancement of learners' systematic and higher-order thinking skills. This approach conditions learners to engage in sequential learning processes, which constitute a solid foundation for engineering problem-solving and the development of innovative solutions. Furthermore, it enables learners to effectively synthesize their prior knowledge with newly acquired concepts. Moreover, the integration of virtual reality technology facilitates the comprehension of complex content while concurrently mitigating constraints related to equipment availability, physical space, and safety in physical classroom settings.

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