Advance Organizer Integrating Visual-Based Programming via Artificial Intelligence of Things to Enhance Advanced Computational Thinking Competency

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***Abstract*—Emerging technologies, such as the Artificial Intelligence of Things (AIoT), pose challenges in education, particularly when students struggle to connect theoretical concepts with practical applications. This gap limits their ability to engage with AIoT and develop computational thinking competencies, such as Critical Thinking, Algorithmic design, Problem-solving, Creativity, and Cooperativity. To address this issue, the Advance Organizer Integrating Visual-Based Programming for Artificial Intelligence of Things (AOVP-AIoT) model, was developed. The model combines structured scaffolding with visual programming to make AIoT concepts more accessible and engaging, fostering computational thinking skills applicable in formal and informal learning settings, including university courses, online training, and professional workshops. The study was conducted in two phases. Phase I involved designing the AOVP-AIoT model by synthesizing data from research publications (2003–2023). Expert review rated the model highly (mean = 4.39, SD = 0.69) across input components, learning processes, and computational thinking competencies. Phase II involved constructing the AOVP-AIoT platform, following the AIoT System Development Life Cycle (AIoT-SDLC) across eight iterative stages. Unlike existing approaches, the platform emphasizes on personalized learning pathways and interactive AI assistance, enchancing adaptability and real-time support. Evaluation results indicated very high quality in infrastructure, intelligence organizer-based management, learning tracking, and performance assessment (mean = 4.69, SD = 0.43). By equipping learners with transferable computational thinking skills, the AOVP-AIoT model addresses educational challenges in AIoT and prepares students for success in industries increasingly shaped by AI and IoT innovations.**

***Keywords*—advance organizer, visual programming, artificial intelligence of things, computational thinking**

I. Introduction

As educators and researchers in the field of AIoT, we have observed firsthand how the integration of IoT and AI is transforming industries and creating new challenges in education. The combination of AI and IoT technologies necessitates understanding how different components—such as sensors, data processing algorithms, and network systems—work together. This complexity poses significant cognitive and practical barriers for learners, as it demands both theoretical understanding and hands-on experience. Moreover, the absence of structured models to effectively integrate prior knowledge with new concepts exacerbates these challenges, leaving students underprepared for addressing real-world AIoT applications. Addressing these issues requires educational approaches that simplify technical concepts, foster computational thinking, and enable students to engage meaningfully with AIoT systems [1]. The development of Artificial Intelligence of Things (AIoT) has enabled the creation of intelligent systems capable of integrating diverse domains, optimizing operations, and supporting decision-making in real-time. These advancements play a pivotal role in enhancing quality of life and addressing complex challenges across industries. To effectively harness the potential of AIoT, computational thinking skills such as problem-solving, algorithmic design, and critical analysis are essential for navigating the technological era [2–4]. This ongoing transformation underscores the urgency of equipping learners with the skills needed to navigate this rapidly evolving landscape. By connecting physical objects seamlessly, IoT enables expansive interconnectivity, while AI augments these systems with near-human decision-making capabilities, thereby optimizing operations across sectors from smart cities to urban infrastructure [3, 5]. In manufacturing, for example, AIoT-driven solutions enhance efficiency, minimize waste, and streamline processes through automation and real-time analytics [2, 6]. Such advancements are reshaping the skills demanded in the modern workforce, prompting a shift in educational approaches to prepare learners for an increasingly technology-oriented environment. In response to this shift, Education 5.0 represents a transformative framework that emphasizes personalized learning, immediate feedback, and enriched digital experiences, ensuring students are well-prepared for this new era [7]. However, incorporating AIoT into educational systems presents challenges due to its technical complexity, requiring specialized knowledge and sophisticated tools [8–10]. To prepare students for this digital shift, education systems must adopt models that help students not only understand new concepts but also integrate them meaningfully with existing knowledge.

The Advance Organizer Model has demonstrated its effectiveness as a learning strategy by structuring new information in alignment with learners' prior cognitive frameworks. This approach aids in making learning more meaningful and improves retention, as it links new content to existing knowledge, thereby fostering a deeper understanding of complex subjects [11]. Applied both before and after learning, the model significantly enhances long-term retention and promotes integrated knowledge transfer [12–14]. Recent implementations in e-learning management systems underscore its role in promoting integrated science process

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skills; by activating prior knowledge and connecting it to real-world applications, the model enhances learning outcomes and supports skill integration [15]. Moreover, when paired with inquiry-based learning, the Advance Organizer Model has shown to enhance problem-solving capabilities, particularly in science education, by guiding learners through complex material in a structured and engaging manner [16]. This structured approach also encourages self-directed learning, empowering students to actively explore questions and engage independently with the material [17].

Visual programming complements this model by offering intuitive graphical interfaces that simplify programming tasks, empowering learners to conceptualize, design, and interact with complex technological systems [18, 19] such as AIOT. By reducing syntax errors and facilitating understanding of fundamental programming concepts like loops and variables, visual programming enables novice learners to navigate complex topics with greater ease [20]. For AIoT education, where learners are required to integrate knowledge from multiple domains, such as hardware, software, and IoT systems, visual programming bridges the gap between theoretical understanding and practical application [21]. Additionally, visual programming is a powerful tool for reinforcing computational thinking (CT) skills—essential competencies within digital learning environments. By providing an interactive platform, visual programming enhances core CT skills such as abstraction and pattern recognition, rendering complex programming concepts more accessible and engaging [22, 23]. Visual programming languages enhance accessibility to abstraction and pattern recognition, allowing users to concentrate on problem-solving. By facilitating the identification and reuse of duplicated code patterns, these languages contribute significantly to software quality improvement [24, 25]. The growing recognition of computational thinking in technology-enhanced education emphasizes the need for tools that support its development [10, 19, 26] Visual programming tools thus play a vital role by offering accessible and practical ways for learners to apply CT in real-world scenarios [23, 27].

Despite these advancements, existing frameworks such as the Imagineering Learning Model have demonstrated the effectiveness of linking theoretical concepts with practical applications [28]. However, there remains a scarcity of research integrating advance organizers and visual programming specifically within the context of AIoT education. While advance organizers have proven effective in enhancing retention and linking prior knowledge with new information, and visual programming facilitates the simplification of complex technical concepts, their combined application to support computational thinking in AIoT remains underexplored. This gap is particularly significant given the interdisciplinary challenges of AIoT, which require learners to synthesize knowledge across hardware, software, and IoT systems while engaging with real-time feedback and practical applications. This study uniquely addresses the gap by integrating advance organizers and visual programming within the AIoT context. While advance organizers support cognitive scaffolding and retention, visual programming simplifies technical complexities and fosters practical interactivity. The main objective of this research is to develop and validate the Advance Organizer Visual Programming via Artificial Intelligence of Things (AOVP-AIoT) model. This framework bridges the gap by enabling learners to connect abstract concepts with real-world AIoT applications, addressing the interdisciplinary and computational challenges of AIoT education.

II. Theoretical Background

The theoretical conceptual framework illustrated in Fig. 1 provides an integrated view of the relationships between Advance Organizer, Visual-Based Programming, and computational thinking within the context of AIoT education.

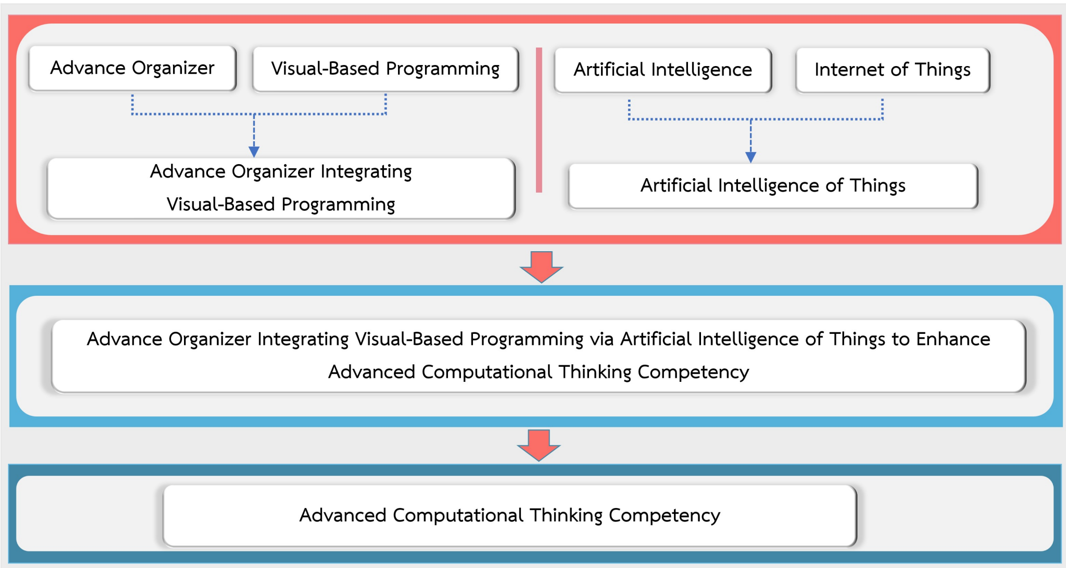

Fig. 1. The theoretical conceptual framework of the AOVP-AIoT model.

A. Advance Organizer

The Advance Organizer Model, a cognitive-based instructional strategy developed by educational psychologist David Ausubel in the 1960s, underscores the importance of anchoring new information to pre-existing knowledge structures to facilitate meaningful learning [11]. Serving as pre-instructional tools, advance organizers present high-level abstract information prior to detailed content, effectively guiding learners' cognitive processing by activating prior knowledge and creating cognitive frameworks that contextualize incoming information, thereby reducing cognitive overload [15, 29].

However, while the model has demonstrated its utility in various contexts—such as enhancing comprehension in ESL classrooms [13], facilitating inquiry-based learning [16], and supporting hypothesis-driven problem-solving [17]—its integration with technology in AIoT contexts remains limited. For example, recent implementations like the Imagineering Learning Model [28] have shown that linking theoretical concepts with IoT applications fosters creativity and critical thinking. Yet, such models often fail to adequately incorporate computational thinking and real-time feedback mechanisms, leaving a significant gap in supporting learners as they navigate AIoT complexities. This research builds upon these insights by incorporating advance organizers into the AOVP-AIoT framework to create structured scaffolding that aligns abstract concepts with hands-on applications in AIoT systems.

B. Artificial Intelligence of Things within a Visual-Based Programming Environment

Artificial Intelligence of Things (AIoT) integrates the data analysis and decision-making capabilities of Artificial Intelligence (AI) with the connectivity of the Internet of Things (IoT). This integration enables intelligent systems to autonomously collect, interpret, and act on data, unlocking innovative possibilities across industries. While AIoT holds potential for various applications, studies primarily highlight its role in improving the efficiency and reliability of IoT systems through tools that enhance real-time responsiveness and operational effectiveness [30, 31]. Visual tools for IoT automation, such as those discussed by [32, 33], enable accessible and efficient IoT system design. However, their application in education remains underexplored, with limited focus on how they can simplify technical concepts for learners and foster deeper engagement with AIoT systems. Similarly, self-healing IoT systems, as proposed by [32], enhance reliability, suggesting potential extensions to adaptive learning technologies. Yet, these applications have not been fully realized in structured educational frameworks, particularly for computationally intensive domains like AIoT.

A Visual-Based Programming Environment (VBPE) simplifies coding by replacing traditional text-based syntax with intuitive visual elements such as blocks and flowcharts. By reducing cognitive barriers, VBPEs make programming more accessible, particularly for beginners or those with limited technical expertise [34]. VBPEs are valuable in education as they promote computational thinking and problem-solving by enabling learners to visually explore and manipulate complex systems and algorithms. These tools support both foundational and advanced learning, particularly in contexts like IoT and robotics education [21]. However, despite their effectiveness in engaging learners, current VBPEs often lack features like real-time interactivity, which are critical for hands-on exploration of AIoT systems.

Integrating IoT within a VBPE creates an accessible platform for learners to explore IoT concepts through visual tools. This approach enables students to interact with IoT networks and manage connected devices intuitively, making IoT technology more approachable [30, 35]. Research demonstrates that VBPEs support real-time data monitoring and sensor management, enabling students to experiment with IoT systems hands-on. These environments help learners develop practical skills in system design, troubleshooting, and IoT application development [32, 36]. The addition of real-time monitoring and feedback systems in a VBPE could further enhance learners' understanding of the dynamic nature of AIoT networks, allowing them to explore complex systems in an interactive and adaptive manner.

When combined with AI, VBPEs provide learners with an intuitive platform to engage with AI concepts, such as machine learning, without requiring extensive programming skills. Research shows that VBPEs enable learners to visually manipulate AI models, fostering a deeper understanding of AI processes and concepts [37, 38]. By enhancing students' analytical skills, these visual interfaces allow learners to apply AI in problem-solving scenarios, effectively bridging the gap between theoretical knowledge and real-world applications [39, 40]. However, further integration of AI-driven tools within VBPEs could empower learners to engage with predictive modeling and decision-making tasks, essential for mastering AIoT frameworks.

The combination of VBPEs with engaging educational tools offers a platform where learners can interact with AI concepts through visual and intuitive interfaces. By simplifying complex processes, VBPEs allow students to focus on understanding machine learning workflows and decision-making mechanisms, enhancing their ability to connect theoretical knowledge with practical applications. These tools foster critical thinking and problem-solving skills, preparing learners for a technology-driven landscape [41, 42]. The AOVP-AIoT model builds upon these strengths by incorporating real-time feedback and adaptive pathways, enabling learners to seamlessly transition between abstract concepts and practical applications in AIoT contexts.

C. Advance Computational Thinking

Computational Thinking (CT) is a systematic and logical approach to problem-solving, characterized by skills such as abstraction, algorithmic thinking, decomposition, and pattern recognition [4]. These competencies are critical not only in computer science but also across various disciplines, as they enhance the ability to break down complex problems and devise effective solutions [43]. In today's digital age, CT skills empower individuals to interpret, structure, and innovate, making them indispensable for academic success and practical applications. As the technological landscape continues to evolve, fostering CT skills has become a cornerstone of preparing learners to navigate complex, interdisciplinary challenges.

The need for CT skills has grown with technological advancements, and Korkmaz *et al.* [44] utilized the Computational Thinking Scale, which assesses five key aspects: (1) Critical Thinking, based on logic and evidence; (2)

Algorithmic Design, involving logical, sequential solutions; (3) Problem Solving, focusing on overcoming challenges; (4) Cooperativity, fostering teamwork; and (5) Creativity, promoting innovation. While the CTS has been used to evaluate computational thinking competencies, its application across diverse disciplines requires further validation. For example, [45] explored how computational ideas impact science teaching, and R. Scherer and T. Teo [25] investigated the role of programming self-efficacy in fostering understanding of computational concepts. However, existing studies often focus on evaluating CT rather than embedding it within structured educational frameworks that integrate real-world technologies like AIoT. A. Yadav *et al.* [46] highlighted the importance of integrating technology to foster innovation in educational contexts.

To address diverse educational needs, researchers have integrated CT with Bloom's taxonomy, aligning cognitive (knowledge), psychomotor (skills), and affective (values) domains into comprehensive evaluation frameworks. This integration provides a foundation for addressing the complex demands of AIoT education, ensuring that learners not only acquire theoretical knowledge but also develop practical skills and adaptive mindsets. By leveraging these frameworks, educational models can better support learners in applying CT to solving real-world problems and driving innovation.

III. Research Methodology

This study was conducted in two phases following Fig. 2.

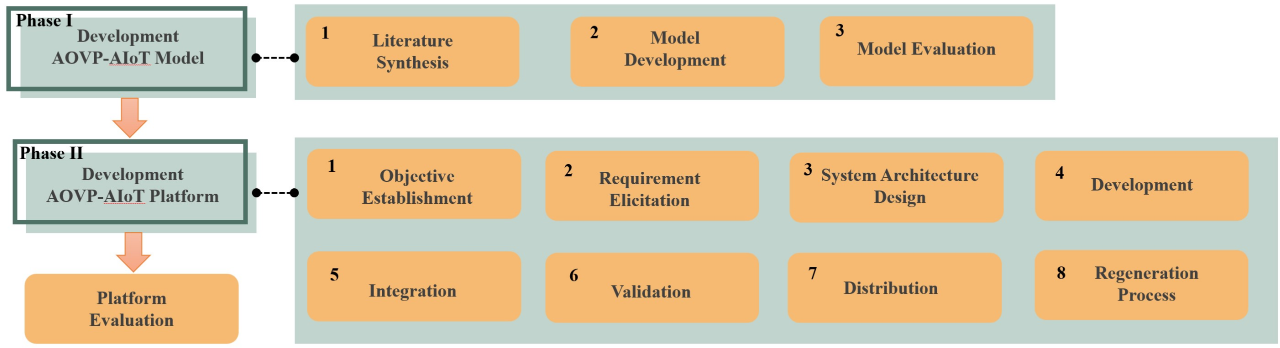

Fig. 2. AOVP-AIoT research methodology.

Phase I. Development of the advance organizer integrating visual-based programming model for artificial intelligence of things

1) Literature Synthesis: Information on integrating advance organizers with visual-based programming was synthesized from academic publications retrieved between 2003 and 2023. To ensure comprehensive coverage, we queried three prominent academic databases: IEEE, Scopus, and Web of Science. The following keywords and Boolean operators were used for the search: ("advance organizer" OR ("visual programming" OR "block-based programming")), ("computational thinking" OR ("artificial intelligence of things" OR "AIoT")).

This search yielded a total of 452 documents across all databases. After an initial screening based on relevance and inclusion criteria (e.g., peer-reviewed journal articles and conference proceedings in English), 36 documents were selected for a more detailed review. These documents were analyzed using a content analysis form, with the primary focus on identifying trends, gaps, and best practices in integrating advance organizers and visual programming within educational contexts.

2) Model Development: The AOVP-AIoT model was designed by combining theoretical insights and practical needs identified through the synthesis. The model aims to bridge theoretical knowledge and practical application in AIoT education.
3) Expert Evaluation: Seven experts specializing in advance organizers, visual programming, AIoT, educational technology, or computational thinking, each with over five years of experience, evaluated the model. A structured questionnaire was employed to assess the appropriateness of the model across three dimensions: input components, learning processes, and computational thinking competencies. The results were analyzed using mean and standard deviation to ensure reliability.

The findings from Phase I served as the foundational framework for designing the AOVP-AIoT platform in Phase II, ensuring alignment between the theoretical model and practical implementation.

Phase II. Development of advance organizer integrating visual-based programming for artificial intelligence of things platform

1) Platform development followed the Artificial Intelligence of Things System Development Life Cycle (AIoT-SDLC) as outlined in prior research [47–53]. This process involved eight key stages:
   a) Objective Establishment: Define the goals of the AOVP-AIoT Platform to enhance advanced computational thinking competencies. The platform aims to meet the demands of 21st-century skills by fostering collaboration between learners and AI in structured learning activities aligned with the AOVP-AIoT model.
   b) Requirement Elicitation: Analyze the needs of learners and instructors to inform the design of structured content and activities. The platform focuses on personalized learning experiences tailored to individual skill levels and learning goals.
   c) System Architecture Design: Develop a conceptual framework based on elicited requirements, incorporating features such as user interfaces, access to

learning resources, AI-based assistance, and project performance assessment, with an emphasis on supporting advanced computational thinking.

d) Development: Construct the platform in accordance with the system architecture. The platform includes four core components: infrastructure, intelligence organizer-based learning management, a learning tracking system, and a project performance assessment module. Each component was designed to align with the AOVP-AIoT model's objectives.

e) Integration: Integrate submodules of the AOVP-AIoT platform into a cohesive system. Rigorous testing ensures seamless functionality of IoT and AI technologies within the platform.

f) Validation: Validate the platform's accuracy and operational consistency, and user satisfaction by employing systematic verification of AI inference, actuator control, and usability testing. Validation metrics included precision rates of AI inference models, response time for actuator control, and feedback collected from user testing sessions. These metrics ensured that all subsystems adhered to defined operational standards and aligned with the goals of the AOVP-AIoT model.

g) Distribution: Distribute the platform to users for pilot testing, focusing on evaluating key performance areas such as coordination capabilities, simultaneous resource access, user engagement, and system stability. Cloud-based accessibility was tested through multi-user scenarios to ensure scalability and efficient resource allocation. Feedback collected during the distribution phase was systematically analyzed to identify usability challenges and refine the platform for enhanced meaningful learning experiences.

h) Regeneration Process: Address malfunctions through corrective actions to improve platform reliability. The iterative process includes debugging and implementing feature enhancements to optimize meaningful learning.

2) The developed platform was evaluated by seven experts selected for their expertise in platform and educational technology. All experts have at least five years of experience in relevant fields. The evaluation employed a questionnaire designed to assess platform quality, with results analyzed using mean and standard deviation calculations.

The evaluation of both Phase I and Phase II was based on a 5-point Likert scale [54], with the following interpretation criteria in Table 1:

Table 1. Interpretation criteria for 5-point likert scale scores

Average Score Range	**Interpretation**
4.50–5.00	Very High
3.50–4.49	High
2.50–3.49	Moderate
1.50–2.49	Low
1.00–1.49	Very Low

IV. Research Findings

This section consists of two phases: Phase I: Development of the AOVP-AIoT Model and Phase II: Development of the AOVP-AIoT Platform.

A. Phase I: Development of the AOVP-AIoT Model

1) Synthesizing the AOVP process

An extensive review of related research was conducted to gather key information on teaching approaches that utilize the Advance Organizer Model and those that employ Visual-Based Programming. The findings from this synthesis are presented in Table 2.

Table 2. Synthesizing results of the organizer visual programming process

The advance organizer model [13, 55–57]	**Learning process of the VBP** [58–61]	**Learning process of the AOVP**
1. Clarify the aims of the lesson	1. Identify	1. Identify Problem
	2. Clarify	2. Clarify scope
2. Presentation of the advance organizer		3. Present Visual Organizer
3. Prompting awareness of relevant knowledge		4. Activate Prior Knowledge and Link to New Ideas
4. Present Material and link material to organizer	3. Decompose Task	5. Decompose Task
	4. Abstraction	6. Abstraction concept
5. Make logical order of learning material explicit.	5. Algorithmic Thinking	7. Design System and Materials
		8) Algorithmic Thinking
6. Integrative reconciliation and active reception learning	6. Code	9. Develop
7. Elicit critical approach to subject matter		10. Evaluate and Reengineer

2) Developing the AOVP-AIoT model

Based on the synthesized information, a conceptual framework for the AOVP-AIoT Model was developed. The conceptual model is presented in Fig. 3.

This stage was related to the design of the elements of the AOVP-AIoT model. The learning management model is structured into three main components: a) input components b) learning process components, and c) advanced computational thinking competency and feedback components.

1) **The input components**, required before commencing the learning process, consist of six elements:

a) Learner Analysis: Examines learners' prior knowledge and practical skills, particularly in areas related to AIoT technology development.

b) Learning Objectives: Defines objectives to ensure learners can develop AIoT projects and demonstrate advanced computational thinking competencies.

c) Instructional Design: Planned by the instructor, this design incorporates principles of the Advance

Organizer Model to connect prior knowledge with new AIoT concepts. This process is facilitated through the AOVP-AIoT Platform to strengthen learners' advanced computational thinking competencies.

d) Structured Learning Content: Covers both theoretical and practical knowledge in AIoT projects, including visual programming, machine perception, sensors, actuator control, cloud platform processing, and advanced visual programming for AI development. Topics include data acquisition, model training, model evaluation, inference, server simulation, real-time communication, and responding to AI inference commands.

e) Learning Activities: Activities are categorized as follows:

Instructor Activities: Prepare the visual organizer, design learning activities using the platform, and foster collaborative learning. The instructor introduces AIoT concepts, connects them to relevant principles, and uses interactive concept maps for meaningful learning. Regular progress monitoring, authentic assessment, and immediate feedback are also provided.

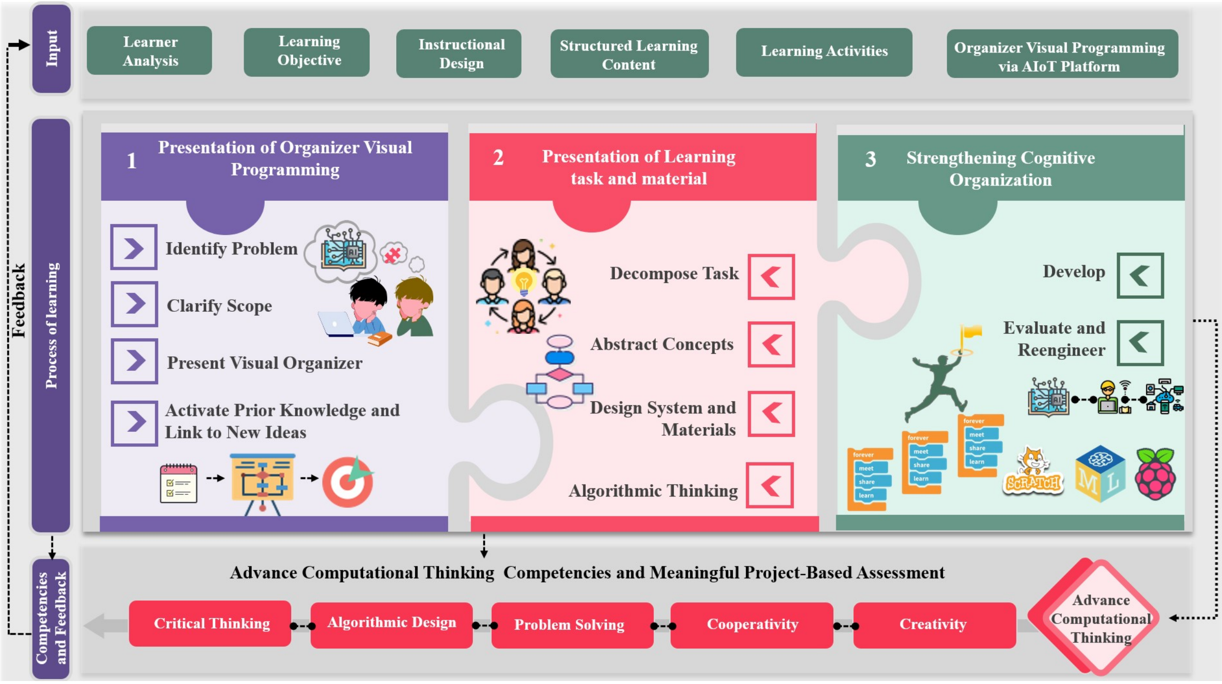

Fig. 3. An overview of the AOVP-AIoT model.

Learner Activities: Set goals to develop critical thinking, algorithmic design, problem-solving, collaboration, and creativity. Learners engage in project development, self-assessment, and peer evaluation while documenting outcomes in a learning log.

f) Organizer Visual Programming Platform: Comprises four components:

Infrastructure: Includes hardware and software essentials such as machine perception devices, microcontrollers, visual programming languages, cloud services, and networks.

Organizer-Based Learning Management: Provides structured learning resources, integrates generative AI for feedback, and supports seamless system integration.

Learning Track System: Offers functionalities like learning logs, communication tools, group discussions, interactive mind maps, and a LiveLab monitor.

Project Performance Assessment: Delivers authentic assessment reports and immediate feedback to guide learners.

2) **Learning Process Components**: This component is structured around activities derived from the Advance Organizer Model and the visual programming learning process, as follows:

a) Identify Problem: Brainstorm and define real-world problems solvable using AIoT technology.

b) Clarify Scope: Refine the project's boundaries and limitations to ensure a manageable scope.

c) Present Visual Organizer: Use visual tools like mind maps, flowcharts, or concept maps to outline the structure of the project and key components.

d) Activate Prior Knowledge and Link to New Ideas: Reflect on prior IoT and AI knowledge and connect it to new project applications, such as integrating AI for predictive analytics.

e) Decompose task: Break down the overall project into sub-tasks such as sensor setup, collect data from machine perception devices, AI model training, and system integration.

f) Abstraction Concept: Identify core principles, removing extraneous details to focus on essential concepts. For instance, simplify data acquisition to include only its fundamental processes.

g) Design System and Materials: Plan system architecture and select tools necessary for project implementation.

h) Algorithmic Thinking: Develop logical sequences of tasks, ensuring steps are executable and cohesive.

i) Develop: Implement the AIoT system, integrate sensors, and test functionality.

j) Evaluate and Reengineer: Evaluate the accuracy and responsiveness of their AIoT system, then refine the algorithms, reconfigure the hardware, or adjust the software to improve performance.

3) **Advanced computational thinking competencies and feedback**

This section defines the evaluation criteria for assessing learners' innovation and advanced computational thinking (ACT) competencies. These competencies are categorized into five factors: critical thinking, algorithmic design, problem-solving, cooperativity, and creativity. Evaluations are divided into two parts:

a) Advanced Computational Thinking Competencies Assessment: This assessment determines students' ACT competencies levels through a self-assessment method, using items adapted from Korkmaz's (2017) Computational Thinking Scales (CTS). The framework, consisting of 30 items on a five-point Likert scale, was refined to focus on relevant aspects and ensure comprehensive coverage of cognitive, affective, and psychomotor domains in line with Bloom's Taxonomy. The validity of the assessment was confirmed through an Index of Item-Objective Congruence (IOC) by five experts.

b) Innovation Assessment: This part uses a rubric rating scale ranging from 0 to 3, where 0 indicates the lowest score and 3 the highest. The specific evaluation aspects are detailed in Table 3:

Table 3. Evaluation aspects to assess learners' innovation

Aspect	Description
Critical Thinking	1. Understanding: Grasping the conceptual framework of an AIoT system. 2. Distinguishing Relevant from Irrelevant Information: Identifying key information while filtering out unnecessary details. 3. Analysis: Analyzing situations to determine effective solutions. 4. Effective Utilization of Tools and Resources: Employing appropriate tools and resources to identify and solve problems efficiently. 5. Evaluation: Assessing the generated solutions for AIoT systems to ensure their effectiveness and feasibility.
Algorithmic design	1. Breaking Down Problems: Decomposing complex tasks into manageable components. 2. Algorithmic Thinking for Problem-Solving: Applying logical sequences and strategies to develop effective solutions. 3. Abstraction in System Architecture Design: Identifying essential elements and relationships within system architecture. 4. Implementing Algorithms in Physical Computing Environments: Applying designed algorithms to real-world, AIoT-based computing systems.
Problem-solving	1. Defining and Clarifying the Problem: Clearly identifying and articulating the core issue to be addressed. 2. Distinguishing Relevant from Irrelevant Information: Selecting key information essential for resolving the problem while filtering out unnecessary details. 3. Systematic Planning and Management: Developing a structured plan to approach and manage the problem-solving process efficiently. 4. Constructing and Maintaining Conceptual Models and Physical Prototypes: Creating and refining models and prototypes to represent and test solutions. 5. Testing, Debugging, Integrating, and Validation: Verifying and refining solutions through testing, debugging, and validating the integration of components. 6. Regeneration Processes: Continuously improving solutions by iterating and refining based on feedback and new insights.
Creativity	1. Generating or Restructuring Various Ideas: Developing new concepts or rethinking existing ones to find alternative solutions. 2. Generating Requirements Elicitation: Identifying and defining requirements in innovative ways to address specific needs. 3. Generating or Restructuring Thinking for the Design Problem-Solving Process: Reimagining the design process to approach problem-solving from different perspectives. 4. Ideational Flexibility and Fluency: Demonstrating the ability to produce a variety of ideas and adapt to new situations or constraints. 5. Transforming Original Ideas into Practical Applications: Converting creative concepts into feasible and functional solutions. 6. Developing Innovative and Valuable Solutions for AIoT Systems: Creating new and effective solutions that add value to AIoT system development and performance.
Cooperativity	1. Cooperative Practices to Organize Ideas and Develop Goals or Objectives: Collaborating with others to structure ideas and establish clear goals for the task or project. 2. Cooperative Practices to Represent and Share Concrete Ideas in Problem-Solving Processes: Effectively communicating and sharing concrete ideas within the team to contribute to collective problem-solving. 3. Cooperative Practices to Formulate Technical Opinions for Solutions: Collaborating to develop and refine technical insights and opinions that contribute to viable solutions.

3) Evaluation result of the AOVP-AIoT model

This section presents the evaluation of the appropriateness of combining the Advance Organizer with visual-based programming in the learning model. The results of the expert evaluation are summarized in Table 4.

Table 4. Evaluating the appropriateness of the AOVP-AIoT model

	Evaluation list	Mean	S.D.	Level
Input Components	1. Learner analysis	4.43	0.73	High
	2. Learning objectives	4.71	0.45	Very High
	3. Instructional Design	4.43	0.49	High
	4. Structured Learning Content	4.43	0.73	High
	5. Learning Activities	4.29	0.70	High
	6. Organizer Visual Programming Platform	4.71	0.45	Very High
	Total of Input Components	**4.50**	**0.59**	**Very High**
Learning Process Components	1. Identify Problem	4.29	0.70	High
	2. Clarify Scope	4.43	0.73	High
	3. Present Visual Organizer	4.29	0.70	High
	4. Activate Prior Knowledge and Link to New Ideas	4.43	0.73	High
	5. Decompose Task	4.29	0.70	High
	6. Abstraction Concept	4.29	0.70	High
	7. Design System and Materials	4.29	0.70	High
	8. Algorithmic Thinking	4.32	0.71	High
	9. Develop	4.29	0.70	High
	10. Evaluate and Reengineer	4.43	0.73	High
	Total of Learning Process Components	**4.34**	**0.71**	High
ACT competencies and feedback components	1. Critical Thinking	4.43	0.73	High
	2. Algorithmic Design	4.43	0.73	High
	3. Problem Solving	4.57	0.73	Very High
	4. Creativity	4.29	0.70	High
	5. Cooperativity	4.43	0.73	High
	Total of ACT competencies and feedback components	**4.43**	**0.72**	**High**
Total		**4.39**	**0.69**	**High**

B. Phase II. Development of Advance Organizer Integrating Visual-Based Programming for Artificial Intelligence of Things (AOVP-AIoT) Platform

1) Development of the AOVP-AIoT platform

We developed the AOVP-AIoT platform as illustrated in Fig. 4. The platform's usage varies based on the user's role, specifically for lecturers and learners.

For lecturers, their responsibilities include defining learning objectives and outcomes, setting up the learning environment, and preparing learning materials and structured content for the AOVP-AIoT platform. Additionally, lecturers are responsible for evaluating project outcomes and providing immediate feedback.

Learners begin by conducting a self-assessment to evaluate their levels of Advanced Computational Thinking (ACT) competencies, identifying their current knowledge, skills, and attitudes required for effectively using computers to solve real-world problems. Next, learners clarify the lesson's objectives, develop an understanding of the basic concepts of AIoT, and establish connections between fundamental and advanced AIoT system concepts. They then proceed by following the learning steps outlined in the Learning Process Component.

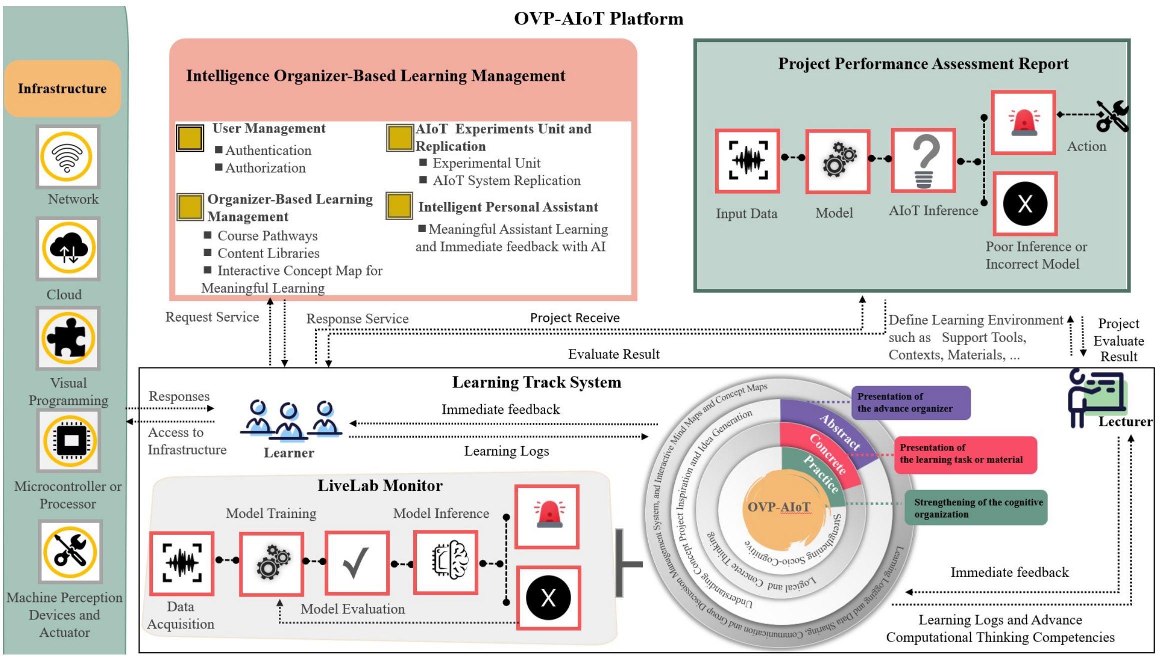

Fig. 4. An overview of the AOVP-AIoT platform.

During the learning process, learners are expected to document their progress by creating a learning log, developing innovative solutions, and engaging in discussions to share and compare results with other groups. Upon completing the learning activities, learners conduct a final self-assessment to re-evaluate their levels of Advanced Computational Thinking (ACT) competencies and reflect on their development.

To support the learning process, the AOVP-AIoT Platform offers four key modules including

1) Infrastructure consisting of five key components: a) Machine Perception Devices and Actuators, b) Microcontroller or Processor, c) Visual Programming Language, d) Cloud Platform and Services, and e) Network
2) Intelligence Organizer-Based Learning Management consisting of four key components:
   a) User Management: This component involves user authentication and authorization for accessing the platform, ensuring secure and appropriate use.
   b) Intelligence Organizer-Based Learning Management: This component supports personalized learning and provides resources related to AIoT and its applications. It includes features such as Course Pathways, Content Libraries, and an Intelligence Concept Map for Meaningful Learning that facilitates interactive and meaningful learning experiences.
   c) AIoT Experiments Unit and Replication: This component focuses on simulating AIoT operations and providing hands-on learning experiences through experimental and practical modules. The AIoT Experiments Unit and Replication system is designed to provide hands-on learning through the simulation of AIoT operations, integrating central processing, AI applications, and IoT device control. At the core of the system, the Raspberry Pi Server functions as the central processing unit, collecting data from environmental interactions and serving as an intermediary between users and the system through an API connection with Scratch. This enables the management of AI-based simulations and IoT devices. The system incorporates visual programming with machine learning to create interactive AI applications, allowing learners to input datasets, train models, and receive real-time feedback. Additionally, the system includes an IoT control component that supports remote monitoring and management of devices via Wi-Fi using SSH or VNC, while the OneGPIO Extension facilitates the control of connected hardware such as LEDs, motors, and other IoT devices.
   d) Intelligent Personal Assistant: This component provides personalized guidance and support to learners. It leverages generative artificial intelligence to function as an intelligent assistant, enhancing the learning experience by stimulating critical thinking and offering tailored recommendations.
3) The Learning Track System supports learning through the recording of learning activities and data sharing, as well as the management of communication and group discussions. It includes tools for creating concept maps to connect ideas, aiding in project analysis, planning, organization, decision-making, and solution presentation. Additionally, the system features a LiveLab Monitor for tracking progress within laboratory environments.
4) The Project Performance Assessment Report involves evaluating the effectiveness of AIoT projects and assessing advanced computational thinking skills through authentic assessments. It also provides immediate feedback to support continuous improvement and learning.

2) Evaluation results on the quality of the AOVP-AIoT platform

This section presents the evaluation of the platform's quality in supporting the learning experience. The results from expert assessments are summarized in Table 5.

Table 5. Evaluation results on the quality of the AOVP-AIoT platform

	Evaluation list	*Mean*	*S.D.*	Level
Infrastructure	1. Machine perception devices and actuator	4.71	0.45	Very High
	2. Microcontroller or Processor	5.00	0.00	Very High
	3. Visual Programming Language	4.71	0.45	Very High
	4. Cloud Platform and Services	4.86	0.35	Very High
	6. Network	4.86	0.35	Very High
	Total of Infrastructure	**4.83**	**0.32**	**Very High**
Intelligence Organizer-Based Learning Management	1. Organizer-Based Learning Management	4.71	0.45	Very High
	2. AIoT Experiments Unit and Replication	4.86	0.35	Very High
	3. Intelligent Personal Assistant	4.71	0.45	Very High
	4. Organizer-Based Learning Management	4.71	0.45	Very High
	Total of Intelligence Organizer-Based Learning Management	**4.75**	**0.43**	**Very High**
Learning Track System	1. Learning Logging and Data Sharing	4.71	0.45	Very High
	2. Communication and Group Discussion Management System	4.57	0.49	Very High
	3. Interactive Mind Maps and Concept Maps	4.57	0.49	Very High
	4. LiveLab Monitor	4.57	0.49	Very High
	Total of Intelligence Organizer-Based Learning Management	**4.61**	**0.48**	**Very High**
Project Performance Assessment Report	1. Advance Computational Thinking Assessment Report	4.57	0.49	Very High
	2. Feedback	4.57	0.49	Very High
	Total of Project Performance Assessment Report	**4.57**	**0.49**	**Very High**
Total		**4.69**	**0.43**	**Very High**

V. Discussion

This research evaluated the efficacy of the AOVP-AIoT model, an innovative instructional framework aimed at enhancing computational thinking competencies within the context of Artificial Intelligence and the Internet of Things (AIoT). The evaluation began with expert assessments of the model, focusing on key components such as input, learning processes, and feedback mechanisms. Results demonstrated an average score of 4.39 (SD = 0.69), underscoring the model's ability to support critical thinking, algorithmic design, and problem-solving in computational contexts. Experts emphasized the model's structured approach, which bridges the gap between prior knowledge and new concepts, enabling learners to better navigate the interdisciplinary challenges of AIoT education. These findings align with Lin *et al*. (2021), who emphasized the importance of cognitive scaffolding and interactive tools in enhancing computational thinking skills in AIoT contexts [1].

The implementation of the AOVP-AIoT platform further validated its effectiveness, receiving an impressive average score of 4.69 (SD = 0.43) across critical dimensions such as organizer-based management, learning tracking, and performance assessment. The platform's integration of real-time feedback, AI-driven personalized guidance, and interactive tools was highlighted as a key strength, enabling learners to refine their problem-solving strategies dynamically. This aligns with recent advancements in AIoT-driven education systems that leverage artificial intelligence to deliver adaptive and personalized learning experiences [8]. Unlike earlier platforms that lacked real-time adaptive feedback mechanisms, the AOVP-AIoT platform uniquely supports a personalized, interactive learning environment, addressing critical challenges in teaching complex AIoT systems [2].

The AOVP-AIoT model's integration of advance organizers and visual programming offers several unique advantages. The advance organizer framework facilitates the connection between prior knowledge and new concepts, fostering deeper understanding and improved knowledge retention [11]. When applied to complex topics such as AIoT, advance organizers help learners structure new information effectively, as demonstrated in recent studies on cognitive frameworks in STEM education [16]. Meanwhile, visual programming simplifies the learning process by reducing cognitive barriers associated with traditional syntax, making programming more accessible to a diverse range of learners [20]. These tools enable students to focus on computational thinking skills such as algorithmic design and problem decomposition, which are essential for addressing real-world challenges in AIoT systems.

Moreover, the platform supports learners in translating theoretical knowledge into practical applications. During pilot testing, learners applied the AOVP-AIoT model to design a real-time mask-wearing monitoring system, demonstrating its potential for addressing practical and societal challenges [33]. This aligns with findings from other studies that highlight the role of computational thinking frameworks in preparing learners for real-world problem-solving in technology-driven contexts [4].

While the findings are promising, certain limitations should be acknowledged. The relatively small sample size of the expert evaluations restricts the generalizability of the results. Further research with larger and more diverse populations is needed to validate these findings comprehensively. Additionally, this study was conducted in a specific educational context, and future research should explore the model's applicability in other settings, such as primary and secondary education or professional training environments. Long-term studies are also required to evaluate the sustained impact of the model on learners' computational thinking and problem-solving skills. These future directions align with ongoing efforts to expand the relevance and scalability of AIoT education frameworks [2] and their integration into digital-era learning environments [7].

In conclusion, the AOVP-AIoT model represents a significant contribution to AIoT education by addressing critical challenges in integrating interdisciplinary knowledge, fostering computational thinking, and supporting practical applications. By combining advance organizers and visual programming, the model equips learners with the skills needed to thrive in a rapidly evolving technological landscape. These findings emphasize the importance of adaptive, technology-driven educational tools in bridging knowledge gaps and preparing students for the complexities of the digital era [10].

VI. Conclusion

The AOVP-AIoT model introduced in this study offers an innovative educational framework designed to enhance students' advanced computational thinking competencies within the realm of Artificial Intelligence of Things. By integrating the Advance Organizer Model with visual programming, the model addresses the challenges of teaching AIoT concepts, linking new information to prior knowledge to foster deeper comprehension. Visual programming simplifies complex programming tasks, enabling students to intuitively conceptualize, design, and navigate technological intricacies while fostering greater engagement.

The inclusion of the AOVP-AIoT Platform enhances the model by promoting collaborative learning, where students can work alongside AI systems. The platform's personalized assistance and interactive feedback mechanisms help students achieve their learning goals and improve engagement with advanced technologies. By providing a structured pathway for mastering complex technological skills, the model equips learners to meet the demands of a rapidly evolving digital landscape. This integrated approach not only provides a structured pathway for mastering complex technological skills but also aligns seamlessly with the transformative goals of Education 5.0, emphasizing personalized learning, real-time feedback, and digital innovation. Future extensions of the AOVP-AIoT model could incorporate real-time data analytics, adaptive learning systems, and integration with emerging technologies such as virtual and augmented reality, creating immersive and impactful educational experiences. As educational environments continue to evolve, the AOVP-AIoT model and platform are poised to play a vital role in equipping learners with the competencies necessary to thrive in a technology-driven future.

Moreover, the AOVP-AIoT model offers a versatile foundation that can be adapted for various educational contexts and industries. Its design enables educators to replicate the framework in domains beyond AIoT, such as data analytics, robotics, and smart city technologies. The combination of visual programming and advance organizers provides a scalable solution for institutions aiming to enhance digital literacy and computational thinking across diverse curricula. Additionally, the model serves as a template for developing adaptive learning platforms in other fields, ensuring learners with varying technical backgrounds can effectively engage with complex technological concepts.

This study contributes significantly to bridging the gap between theoretical knowledge and real-world application in AIoT education. By fostering computational thinking and equipping learners with advanced problem-solving skills, the model supports workforce readiness in industries increasingly shaped by AI and IoT innovations. The AOVP-AIoT platform's integration of AI-driven feedback and personalized learning pathways sets a new standard for interactive, technology-enhanced education, paving the way for transformative learning experiences. Additionally, its potential for expansion into emerging technologies, such as virtual and augmented reality, underscores its broader applicability and impact in creating immersive educational environments. As such, the AOVP-AIoT model and platform can act as a catalyst for reimagining technology-driven learning, fostering innovation, and driving global competitiveness in the digital era.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Mr. Sant Phanichsiti was responsible for conducting the research, designing the study, collecting data, drafting the initial manuscript, and revising the paper. Professor Dr. Prachyanun Nilsook provided guidance on research methodology, reviewed the manuscript, and contributed to refining its structure and clarity. Professor Dr. Pallop Piriyasurawong advised on the design of research instruments, evaluated the appropriateness of the study framework, and contributed to improving the manuscript's quality. All authors reviewed, contributed to, and approved the final version of the manuscript.

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