Artificial Intelligence Education Studies
Volume 1, Issue 2, 2025, Page 32-47
https://doi.org/10.6914/aiese.010203

Artificial Intelligence Education Studies

Prompt Engineering as a 21st-Century Literacy: A K-12 Curriculum Design and Assessment Framework

Emily SONG

Hong Kong Center of Social Sciences Email: lisophiahk@gmail.com https://orcid.org/0009-0008-3326-6397

Abstract

The rapid proliferation of generative Artificial Intelligence (AI) necessitates a fundamental shift in educational paradigms, positioning prompt engineering (PE) as a crucial 21st-century literacy for K-12 students. This paper argues that PE transcends mere technical skill, embodying a complex interplay of critical thinking, iterative refinement, creative problem-solving, and ethical awareness. It proposes a comprehensive K-12 curriculum framework for PE, grounded in Backward Design principles and leveraging Project-Based Learning (PBL) and Computational Thinking (CT) for authentic skill development across elementary, middle, and high school levels. Furthermore, a multi-dimensional assessment framework is presented, incorporating formative and summative strategies, along with detailed rubrics, to evaluate the multifaceted nature of PE literacy. The paper also addresses the significant ethical considerations inherent in PE education, including algorithmic bias, data privacy, and student agency, and outlines essential competencies and professional development models for empowering educators. By fostering PE literacy, K-12 education can equip students to critically and creatively engage with AI, preparing them for a future where human-AI collaboration is ubiquitous.

Keywords Prompt Engineering; AI Literacy; K-12 Education; Curriculum Design; Assessment; Generative AI.

1 Introduction: The Imperative of Prompt Engineering as a Foundational 21st-Century K-12 Literacy

1.1 The Evolving Educational Landscape in an AI-Driven World

The 21st century is characterized by unprecedented technological advancement, with Artificial Intelligence (AI) emerging as a transformative force reshaping societies, economies, and consequently, educational systems. Students currently in K-12 education will enter a workforce and civic life profoundly influenced by AI; they are expected to navigate a "2035 economy" and confront a "radically different AI-driven, globally connected economy"[1]. This evolving landscape demands new literacies that extend beyond traditional subject matter knowledge. The advent and increasing accessibility of Generative AI (GenAI) tools, particularly Large Language Models (LLMs) capable of producing "human-like text in a conversational mode"[2], have democratized access to sophisticated AI capabilities. This democratization makes the ability to effectively interact with these tools—a skill known as prompt engineering—universally relevant. The ease with which individuals can now engage with powerful AI systems creates an urgent, not merely important, need for foundational literacy in how to guide and interpret these systems. Without such skills, students risk becoming passive consumers of AI-generated content rather than critical and empowered users, potentially exacerbating existing digital and knowledge divides.

1.2 Defining Prompt Engineering (PE) as a 21st-Century Literacy

Prompt engineering (PE), in this context, is conceptualized not as an isolated technical competency but as a comprehensive 21st-century literacy. It involves the art and science of "crafting, refining, and optimizing prompts to

© **The Authors 2025.** Article History Received: April 19, 2025; Accpted: May 10, 2025; Published: June 30, 2025. ***Artificial Intelligence Education Studies***, ISSN 3079-8086 (print), ISSN 3079-8094 (online), a Quarterly, founded on 2025, published by Creative Publishing Co., Limited. Email: wtocom@gmail.com, https://ai-es.org, https://cpcl.hk.

obtain high-quality outcomes from AI models"[3]. This process inherently requires critical thinking to formulate precise queries, iterative refinement based on AI responses, creativity in exploring AI capabilities, and an ethical awareness of the implications of AI use[1]. Indeed, "Prompt Engineering Mastery" is identified as a "premium skill," with frameworks like "Economic Prompt Engineering" explicitly designed to build "critical-thinking skills"[1]. This broader understanding of PE aligns it with established 21st-century competencies such as critical thinking, adaptability, systems analysis, and ethical leadership, which are increasingly demanded by the modern economy and higher education institutions[1].

1.3 Rationale and Significance for K-12 Education

The K-12 educational stage is critical for laying the groundwork for PE literacy. Introducing these skills early prepares students not only for the advanced demands of higher education but also for future careers where AI interaction will be commonplace[1]. Equipping K-12 students with AI literacy is vital for them to "effectively engage with the increasingly complex and fluid information environment of today"[4]. However, a significant gap currently exists. While students and teachers are increasingly utilizing GenAI tools, often driven by curiosity or immediate need, this adoption is frequently ad-hoc. There is a demonstrable "lack of frameworks that focus on leveraging GenAI in education settings," which leaves many educators unprepared to guide students effectively[5]. Surveys indicate that while GenAI usage is rising among students and educators, "confusion remains about what counts as acceptable use," and stakeholders express a strong desire for "additional AI policies and guidance"[6]. For instance, in the Fall of 2023, only 18% of educators reported using GenAI, with disparities in training provision, such as urban districts being less likely to offer GenAI training[6]. This unstructured approach means that students' exposure to and understanding of PE can be highly variable, dependent on individual teacher initiative rather than systemic curriculum design, leading to potential inequities and unfulfilled learning potential. Delaying formal, structured PE education risks creating a generation of students ill-equipped to critically engage with, leverage, or challenge AI systems, impacting not just their future employability[1] but also their civic participation and ability to make informed decisions in an AI-shaped society.

1.4 Thesis Statement and Article Roadmap

This article aims to address this critical need by proposing a comprehensive curriculum design and assessment framework for establishing prompt engineering as a foundational K-12 literacy. It will explore the conceptual underpinnings of PE as a literacy, delineate pedagogical approaches suitable for its instruction, detail a K-12 curriculum structure with grade-specific learning progressions, and outline a multi-dimensional assessment model. Furthermore, the article will examine the crucial ethical considerations inherent in PE education and discuss the necessary professional development to prepare educators for this new pedagogical domain. The subsequent sections will systematically build this argument, beginning with a deeper conceptualization of PE, followed by pedagogical foundations, the proposed curriculum and assessment frameworks, ethical challenges, and finally, teacher preparedness and concluding recommendations.

2 Conceptualizing Prompt Engineering: Beyond Technical Skill to Critical Literacy in the K-12 Context

2.1 Defining Prompt Engineering: Core Components and Processes

Prompt engineering is fundamentally the art and science of designing effective inputs—prompts—to elicit desired outputs from GenAI models[3]. This is not a simple question-and-answer mechanism; GenAI tools are "designed to interact with you through a sequence of prompts," learning from continued refinement and interaction[7]. Effective educational PE is a multifaceted skill encompassing several key components: deep content knowledge relevant to the query, critical thinking to analyze and evaluate AI responses, iterative refinement of prompts to improve outcomes, clarity and precision in language, creativity in exploring AI's potential, collaboration when working in teams, foundational digital literacy, ethical reasoning regarding AI use and its outputs, and contextual integration of AI into broader learning tasks[3]. This list of components underscores that PE literacy extends far beyond the mere technical act of writing a question; it involves a sophisticated cognitive engagement with the AI.

The practice of PE involves a range of techniques. These include foundational approaches such as zero-shot prompting (providing a task without examples) and few-shot prompting (providing a few examples to guide the AI). More advanced techniques involve structured reasoning, like chain-of-thought prompting, which encourages the AI to break down complex problems into intermediate steps. Other categories include hallucination reduction strategies (e.g., Retrieval Augmented Generation - RAG, which grounds AI responses in provided factual documents) and various user-centric strategies that focus on optimizing the interaction for the user's specific needs[3]. The existence of such a diverse array of techniques highlights the depth and complexity of PE as a field of practice.

2.2 Situating Prompt Engineering within the Constellation of 21st-Century Literacies

Prompt engineering does not exist in a vacuum; it is intrinsically linked to and builds upon other established 21st-century literacies. It shares common ground with digital literacy, which is, in fact, listed as one of its core components[3]. It significantly intersects with information literacy, particularly as GenAI reshapes the information landscape; traditional information literacy paradigms are shifting as AI tools become sources of information, bringing new challenges related to information assessment and credibility[4]. PE extends information literacy by requiring users to critically evaluate AI-generated content, which may contain biases or inaccuracies. Similarly, it connects with media literacy by demanding an understanding of how AI-generated media are created and how they can influence perception.

A crucial aspect of PE is its role in enhancing critical thinking. Students must learn to meticulously evaluate AI outputs, identify potential biases, understand the inherent limitations of AI systems, and verify information[1]. The capacity to "verify the accuracy and reliability of information when confronted with bias and misinformation in AI-generated information" is paramount[4]. Thus, PE is not just about getting answers from AI, but about engaging in a cognitive partnership that requires active human intellect, critical evaluation, and a dialogic interaction. The student is not a passive recipient of information but an active shaper of the AI's output, learning through "creativity and resilience" in the interaction process[7]. In this partnership, the "human skills that AI can't replicate"[8], such as nuanced judgment and ethical consideration, become even more critical.

The mention of "hallucination reduction" techniques[3] such as RAG is particularly telling. It implies that PE literacy must inherently include an understanding of AI's fallibility and the skills to mitigate it. This is a significant departure from traditional information retrieval from curated, human-vetted sources. Concerns about "false or misleading information (so-called 'hallucinations')"[2] mean that PE literacy involves developing not only effective questioning techniques but also a healthy skepticism and robust verification strategies for AI-generated content—a more complex cognitive task than evaluating traditional sources.

2.3 The Cognitive Demands of Prompt Engineering

Effective prompt engineering actively fosters higher-order thinking skills. The process of formulating a precise prompt requires analysis of the problem and synthesis of relevant information. Evaluating the AI's response involves critical assessment. Refining prompts based on feedback demands problem-solving and metacognitive reflection[1]. Interdisciplinary learning, which is highly relevant to understanding AI's broad applications, is linked to the development of critical thinking and complex problem-solving skills[9]. For instance, designing prompts to generate "counterarguments" or to facilitate "making connections between new concepts and previous knowledge" directly engages these higher-order cognitive functions[7].

Metacognition plays a vital role. Students must reflect on their prompting strategies, analyze why certain prompts yield better results, and adapt their approaches accordingly[3]. The practices of "iterative refinement" and "reflection" are identified as essential for guiding LLM interactions effectively[3]. This continuous loop of action, reflection, and adaptation is central to both learning PE and developing broader metacognitive awareness. The act of prompting, evaluating, and re-prompting, as necessitated by the interactive nature of GenAI, is in itself a powerful critical thinking exercise. When students are tasked with critically evaluating and iteratively refining AI outputs, rather than passively accepting them, their critical thinking capacities are directly engaged and developed.

To clarify PE's position, Table 1 offers a comparative overview.

Sources: [1, 3, 4]

3 Pedagogical Foundations for Prompt Engineering Education in K-12

Table 1: Defining Prompt Engineering within the 21st-Century K-12 Literacy Constellation

Literacy	Core Definition/Focus	Key Skills Specific to This Literacy	How PE Intersects/Builds Upon/Differs
Prompt Engineering (PE)	Crafting, refining, and optimizing inputs (prompts) to effectively and ethically guide Generative AI tools towards desired outcomes.	Query formulation, iterative refinement, critical evaluation of AI output, ethical AI interaction, creative application of AI, understanding AI limitations.	Applies critical thinking to AI interactions; extends information literacy to AI-generated content; requires digital literacy for tool use; distinct in its focus on human-AI dialogue and co-creation.
Digital Literacy	The ability to find, evaluate, create, and communicate information using digital technologies.	ICT operations, information searching, online communication, digital content creation, digital safety and security.	Foundational for PE; PE utilizes digital tools and platforms, but focuses specifically on the interaction with AI systems within those platforms.
Information Literacy	The ability to recognize when information is needed and to locate, evaluate, and use effectively the needed information.[4]	Identifying information needs, locating sources, evaluating source credibility, synthesizing information, ethical use of information.	PE extends information literacy to AI-generated content, requiring new evaluation skills for AI-specific issues like bias and hallucinations, and verification of AI outputs against other sources.[4]
Media Literacy	The ability to access, analyze, evaluate, create, and act using all forms of communication.	Analyzing media messages, identifying bias/propaganda, understanding media effects, creating media content, responsible media participation.	PE intersects when AI is used to generate or analyze media; requires critical evaluation of AI-generated media and understanding of AI's role in media creation and dissemination.
Critical Thinking	The objective analysis and evaluation of an issue in order to form a judgment.[1]	Analysis, interpretation, evaluation, inference, explanation, self-regulation, problem-solving.	A core component of PE[3]; PE provides a rich context for applying and developing critical thinking skills through the evaluation of AI responses, identification of AI limitations, and refinement of inquiries.[4]

3.1 Leveraging Backward Design for PE Curriculum Development

The Backward Design model, articulated by Wiggins & McTighe, offers a structured approach to curriculum development that is particularly well-suited for a new and evolving literacy like PE[10]. Instead of starting with content to be covered, Backward Design begins with the end in mind:

First, identify desired results: What should students know, understand, and be able to do regarding prompt engineering by the end of a unit or course? These desired results would encompass the core PE competencies identified earlier, such as effective query formulation, iterative refinement, critical evaluation of AI outputs, and ethical application[3].

Second, determine acceptable evidence: How will students demonstrate their achievement of these desired results? This involves designing assessments—both formative and summative—that provide tangible evidence of PE literacy, such as projects, portfolios of prompts and AI interactions, presentations explaining their PE strategies, and critical analyses of AI-generated content.

Third, plan learning experiences and instruction: What knowledge, skills, activities, and resources will enable students to achieve the desired results and demonstrate their understanding through the chosen assessments? This stage involves designing engaging learning activities that progressively build PE skills.

A key principle of Backward Design is its focus on "core concepts and competencies," aiming to reduce cognitive load by concentrating on essential understandings rather than attempting to cover an exhaustive amount of information, all without sacrificing rigor[10]. This is particularly relevant for integrating a dynamic skill like PE, ensuring that students grasp the fundamental principles that can be applied even as AI technologies evolve.

3.2 Project-Based Learning (PBL) as a Vehicle for PE Skill Acquisition

Project-Based Learning (PBL) provides an ideal pedagogical vehicle for developing and applying PE skills in authentic contexts. PBL engages students in "real-world problems and projects," fostering active learning, student-driven inquiry, problem-solving, and collaboration—all of which are crucial 21st-century skills[12]. PBL inherently supports the development of "critical thinking, creative and problem-solving abilities"[13].

Prompt engineering can be seamlessly integrated into PBL units. Students can leverage GenAI tools for various stages of a project, including research, brainstorming and idea generation, receiving feedback on drafts or designs, and even co-creating elements of their final artifacts or presentations[13]. For example, [14] provides concrete examples of students using AI to help choose an artifact for their PBL project or to assist in structuring their presentations. Similarly, in a commerce education context, generative AI can "make commerce education more dynamic" by allowing students to use AI-driven simulations or predictive models within their PBL tasks[13]. The emphasis in PBL to "Start With The End In Mind" by defining the final product and necessary skills[15] aligns perfectly with the principles of Backward Design. This synergy offers a powerful framework: Backward Design provides the structure for what PE competencies to learn, while PBL provides the engaging, authentic context for how to learn and apply these competencies in meaningful ways.

3.3 Integrating Computational Thinking (CT) Principles

Computational Thinking (CT) offers a set of problem-solving skills and concepts that are highly foundational and transferable to effective prompt engineering. Core CT concepts include: decomposition, which is breaking down a complex problem or system into smaller, more manageable parts[16]; pattern recognition, which involves identifying similarities, trends, or regularities in data or processes[16]; abstraction, focusing on essential information while ignoring irrelevant details and representing complex systems with simpler models[16]; and algorithmic thinking, which is developing a step-by-step sequence of instructions to solve a problem or achieve a task[16]. This is directly applicable to designing "prompt-chains and sequencing"[7] or employing "structured reasoning" techniques[3] like chain-of-thought prompting.

Examples of CT integration across various subjects, such as algorithmic thinking in mathematics or music, decomposition in humanities, and abstraction in science[16], can be readily adapted to teach PE. For instance, the "task segmentation" and "prompt sequencing" identified as strategic PE practices[3] are inherently algorithmic. This direct mapping from CT principles to advanced PE techniques suggests that CT should be an explicit component of PE pedagogy, moving beyond its traditional association solely with coding. Adopting these established, student-centered pedagogies—Backward Design for structure, PBL for application, and CT for foundational problem-solving approaches—can demystify prompt engineering. This makes it more accessible and allows for its integration into existing K-12 practices, rather than it being perceived as an isolated, overly technical add-on, thereby facilitating broader adoption and deeper, more meaningful learning.

4 A Framework for K-12 Prompt Engineering Curriculum Design

4.1 Core PE Competencies and Learning Progressions Across K-12 Stages

A scaffolded approach is essential, introducing PE concepts and skills in a manner consistent with students' cognitive development and prior knowledge. The UNESCO AI Competency Framework for Students, with its progression levels of "Understand, Apply, Create"[18], provides a valuable structure for this.

4.1.1 Elementary (Grades K-5)

The primary goal is to build foundational awareness and simple interaction skills. Students should begin to understand AI as a tool created by humans, learn to ask clear and direct questions, and engage in basic prompt-response interactions. Early ethical awareness is crucial, such as understanding that AI can be helpful but can also make mistakes or reflect biases from the data it learned from.

For grades K-2, activities can include interactive storytelling where AI helps generate parts of a story based on student prompts; using AI for simple factual lookups (e.g., "What sound does a lion make?"); and "unplugged" activities focusing on giving clear, unambiguous instructions to a partner, linking to algorithmic thinking[17].

For grades 3-5, activities can involve formulating slightly more complex questions for information retrieval (e.g., "What are three interesting facts about the Amazon rainforest?"); beginning to experiment with how changing a prompt slightly can change the AI's answer; and discussing fairness in simple AI scenarios (e.g., a game AI that always favors one player).

4.1.2 Middle School (Grades 6-8)

Students should develop more sophisticated prompting skills, including iterative refinement. They begin to evaluate AI outputs for relevance and basic accuracy. Introduction to different types of prompts, such as role-playing prompts (e.g., "Act as a historian and explain...") [7], and a deeper exploration of ethical issues like bias in AI-generated content become important.

Activities can include using AI as a research assistant for subject-area projects (e.g., history, science); co-writing stories or poems with AI, focusing on refining prompts to achieve desired stylistic or content goals; engaging in debates about the ethical uses of AI in everyday life[19]; and simple PBL units where AI tools are used for specific tasks like idea generation or information gathering[12].

4.1.3 High School (Grades 9-12)

Students engage with advanced PE techniques, such as chain-of-thought prompting or few-shot prompting to guide AI behavior[3]. A strong emphasis is placed on critical analysis of AI-generated content for accuracy, bias, completeness, and underlying assumptions. Students should apply PE to complex problem-solving, innovation, and creative endeavors. An introduction to the rudiments of AI system design, as suggested by the UNESCO framework (e.g., understanding training data, basic model types)[18], becomes relevant.

Activities can include conducting in-depth research projects where AI is used strategically for literature review, data interpretation (with critical oversight), or hypothesis generation; participating in "AI for Social Good" projects where PE is used to address real-world problems[22]; developing personal or group prompt libraries for specific tasks or subject areas; critiquing existing AI systems and their societal impacts; and engaging in advanced PBLs that require sophisticated AI integration for research, design, and presentation[13].

4.2 Cross-Curricular Integration Strategies

True PE literacy is achieved when it is not taught in isolation as a standalone "tech skill" but is integrated authentically across the curriculum, demonstrating its utility as a versatile tool for learning and problem-solving in diverse domains[9]. AI itself is an interdisciplinary field, drawing from mathematics, computer science, linguistics, and more[9]. This interdisciplinary nature should be reflected in PE education.

English Language Arts (ELA): AI can serve as a brainstorming partner, a tool for generating first drafts, a feedback mechanism for revisions, or an aid for analyzing complex texts by, for example, summarizing passages or identifying literary devices (with careful verification by the student). Students can practice PE by crafting prompts to achieve specific tones, styles, or perspectives in AI-generated text[7].

Social Studies: AI can facilitate historical inquiry by providing access to vast amounts of information (which must be critically evaluated), helping students explore different historical perspectives, or simulating historical scenarios or decision-making processes. PE skills are vital for framing questions that elicit nuanced and historically contextualized responses.

Science: AI can assist in generating hypotheses, analyzing large datasets (under strict human guidance and with awareness of AI's limitations in statistical interpretation[24]), or explaining complex scientific concepts in different ways. Students can learn to prompt AI to act as a virtual lab assistant or a Socratic tutor for scientific principles.

Mathematics: While direct calculation should remain a human skill, AI can be used to explore mathematical concepts, visualize data, or check the logic of problem-solving steps. PE can involve phrasing mathematical problems in ways AI can understand or asking for explanations of theorems.

The Arts: AI tools can generate ideas for artistic compositions, create variations on themes, or even co-create visual art or music[9]. Students can use PE to guide AI in generating art that aligns with specific aesthetic criteria or conceptual goals.

4.3 Examples of PE Learning Activities and Projects

The curriculum should be rich with varied activities. Students can use PE for personal learning, such as creating cloze passages for recall/retention, prompting AI to help connect new concepts to prior learning, using AI in a "learning-by-teaching" scenario (explaining a concept to the AI and asking for feedback), or developing counterarguments for debate preparation[7].

Project-Based Learning (PBL) examples include enhancing the "Taking Action Against Environmental Pollution" project[12] by students using AI to research pollution effects, brainstorm solutions, or draft advocacy materials. "AI for Social Good" projects[22] inherently require PE to define problems, research solutions, and potentially prototype AI-driven interventions. AI-assisted artifact creation and presentation, where students use AI to help design or refine their project deliverables and presentation structures[14], is another example. AI-Enhanced Simulations and Case Studies offer immersive learning experiences where PE is used to navigate scenarios or analyze complex situations, as seen in economics or business education[1].

4.4 Alignment with International Standards

The proposed PE curriculum framework should align with established international standards to ensure coherence and relevance. PE competencies directly support several ISTE standards, including Empowered Learner, Knowledge Constructor, Innovative Designer, and Computational Thinker[25]. The curriculum should also explicitly address the four dimensions of the UNESCO AI Competency Framework for Students: developing a human-centered mindset, understanding and applying ethics of AI, acquiring knowledge of AI techniques and applications, and fostering skills in AI system design (at an appropriate level for K-12)[18]. The progression from "Understand" to "Apply" to "Create" outlined by UNESCO[18] should inform the scaffolding of activities across grade levels.

Integrating PE with PBL and "AI for Social Good" projects can significantly increase student motivation and the perceived relevance of the skills they are learning. When students see how PE can help them tackle authentic, meaningful problems, their engagement and skill acquisition are likely to be deeper and more sustained.

5 Assessing Prompt Engineering Literacy: A Multi-Dimensional Framework for K-12

5.1 Principles of Assessing PE Literacy

Effective assessment of PE literacy should be ongoing and varied, employing both formative assessments to guide learning and summative assessments to evaluate mastery. This involves looking at both the process of prompting and the products generated or problems solved[15]. Benchmarking deliverables within PBL, for instance, serves as a valuable formative assessment technique[15]. Assessment should also be holistic, evaluating the full spectrum of PE competencies. This includes not just the technical skill of writing effective prompts, but also the student's ability to critically evaluate AI outputs, make sound ethical judgments, apply creativity in their interactions with AI, and collaborate effectively when PE is used in group settings[3]. The core components of PE identified in [3] (content knowledge, critical thinking, iterative refinement, clarity, creativity, collaboration, digital literacy, ethical reasoning, contextual integration) should inform assessment design. Finally, assessment must be authentic, situated in meaningful contexts, often through project-based tasks, where students apply PE skills to solve genuine problems or create tangible artifacts, rather than in decontextualized exercises.

5.2 Formative Assessment Strategies for PE

Formative assessments provide crucial ongoing feedback to students and teachers, allowing for adjustments to teaching and learning strategies. These can include observations, where teachers can observe students as they interact with AI tools, noting their prompting strategies, how they refine prompts, and their reactions to AI outputs. Think-alouds, asking students to verbalize their thought processes while they are crafting prompts and evaluating AI responses, can provide deep insights into their understanding and reasoning. Prompt analysis involves regularly reviewing student-generated prompts for clarity, specificity, effectiveness, and evidence of iterative refinement. Quick quizzes or interactive polls can be used to check students' understanding of core PE concepts, terminology, or ethical guidelines[27]. Peer review of prompts and outputs allows students to provide constructive feedback on each other's prompting strategies and the quality of AI-generated outputs, fostering collaborative learning and diverse perspectives[27]. One-

Table 2: K-12 Prompt Engineering Curriculum Framework: Core Competencies, Learning Progressions, and Cross-Curricular Links

Grade Bands	Key PE Competencies (Synthesized from [3])	Learning Objectives/Progression	Sample Cross-Curricular Integration Idea	Links to ISTE/UNESCO
Elementary K-2	Basic Questioning; AI Awareness	Understand that AI is a tool that responds to instructions. Ask simple 'who, what, where' questions to an AI tool. Recognize AI can make mistakes.	Use AI to generate ideas for a class story (ELA). Ask AI for animal sounds (Science).	ISTE: Empowered Learner. UNESCO: Understand (Human-centred mindset, AI techniques).
Elementary 3-5	Clearer Prompting; Simple Iteration; Basic Output Evaluation; Early Ethical Awareness	Formulate clear, multi-word prompts. Experiment with slightly rephrasing prompts to see different outputs. Identify if an AI answer is relevant. Discuss fairness in simple AI scenarios.	Use AI to find facts for a report on a historical figure, comparing AI info with a book (Social Studies). Prompt AI for different ways to describe a character (ELA).	ISTE: Knowledge Constructor. UNESCO: Understand/Apply (Ethics, AI techniques).
Middle School 6-8	Structured Prompting; Iterative Refinement; Identifying AI Strengths/Weaknesses; Understanding Basic Bias	Develop multi-sentence prompts with some context. Refine prompts based on AI feedback to improve results. Compare AI outputs from different tools or prompts. Identify obvious examples of bias in AI responses. Use role-play prompts.	Use AI to brainstorm solutions for a local community problem (Civics/PBL). Prompt AI to explain a scientific concept in multiple ways, then evaluate clarity (Science). Co-write a short play with AI, iteratively refining dialogue (ELA/Drama).[7]	ISTE: Innovative Designer, Computational Thinker. UNESCO: Apply (Human-centred mindset, Ethics, AI techniques).
High School 9-12	Advanced Prompting Techniques (e.g., chain-of-thought, few-shot); Critical & Nuanced Output Evaluation; Ethical Analysis & Responsible Use; Creative & Innovative Application; Rudimentary AI System Understanding	Design complex, multi-turn prompts for in-depth exploration. Critically evaluate AI outputs for accuracy, bias, completeness, and underlying assumptions, cross-referencing with multiple sources. Analyze ethical implications of AI applications. Use PE for complex problem-solving and innovation. Understand basic concepts of training data and model limitations.	Use AI for advanced research in a capstone project, documenting prompt evolution and critically analyzing AI contributions (All Subjects/PBL). Develop an "AI for Social Good" proposal, using PE to define the problem and potential AI solutions.[22] Critique an existing AI application for its societal impact and potential biases (Ethics/Social Studies).	ISTE: All standards. UNESCO: Apply/Create (All dimensions).

on-one check-ins or group discussions allow teachers to gauge understanding, address misconceptions, and discuss challenges students are facing with PE tasks[27].

5.3 Summative Assessment Strategies for PE

Summative assessments evaluate students' overall PE literacy at the end of a learning period. Project-based assessments are natural for PE skills within the context of larger projects where AI tools are utilized. The final project artifact, along with documentation of the PE process, can be evaluated[15]. Portfolio assessment allows students to compile a portfolio showcasing a range of their PE work over time, which might include examples of initial prompts, refined prompts, AI outputs, critical reflections on the process, and applications of PE across different subjects or problem types. Performance tasks involve designing specific tasks that require students to use PE to solve a defined problem, generate a creative product, or critically analyze a complex AI-generated text. Presentations can be used for students to present their projects or PE explorations, explaining their prompting strategies, justifying their choices, and reflecting on what they learned about interacting effectively with AI.

5.4 Developing and Using Rubrics for PE Assessment

Clear, well-defined rubrics are essential for consistent and transparent assessment of PE literacy. Ideally, rubrics should be co-constructed with students when appropriate, as this process can deepen their understanding of the assessment criteria and expectations[15]. Key criteria for PE rubrics should reflect the holistic nature of the literacy and may include prompt clarity, specificity, and context; iterative refinement and adaptability; critical evaluation of AI output; ethical application and awareness of limitations; creativity and innovation in prompting; and collaboration (if applicable)[3, 7, 4, 28]. Existing rubrics for critical thinking[32], creativity, and collaboration[28] can be adapted and integrated to form comprehensive PE rubrics. For instance, criteria related to analyzing and evaluating information from a critical thinking rubric[33] can be tailored to the specific context of evaluating AI-generated information.

5.5 Student Self-Assessment and Reflection in PE

Encouraging students to engage in self-assessment and reflection is crucial for developing metacognitive skills related to PE. Students should be prompted to think about their learning journey, the challenges they encountered, the strategies that were most effective, and how they can improve their PE skills[7]. As noted in [7], "you learn through your creativity and resilience," highlighting the personal learning journey. Tools such as checklists, reflective journals, and individual goal-setting related to PE proficiency can support this process. The act of co-constructing PE rubrics with students[28] can itself be a powerful learning experience, deepening their understanding of what constitutes effective and responsible PE. This aligns with student-centered pedagogical approaches and empowers students to take ownership of their learning.

Table 3: Multi-faceted Assessment Matrix for K-12 Prompt Engineering Literacy

Key Dimension of PE Literacy (Synthesized from [3])	**Dimension Description**	**Formative Assessment Methods (Based on [15])**	**Summative Assessment Methods (Based on [15])**	**Sample Rubric Criteria (Inspired by [28]) (High/Medium/Low)**
Prompt Design & Articulation	Ability to craft clear, specific, contextualized, and appropriately structured prompts to guide AI effectively.	Prompt analysis (teacher/peer); Quick polls on prompt elements; Observation of initial prompting attempts.	Portfolio entry of diverse prompts; Performance task requiring specific output via prompting; Project component focused on prompt design.	High: Consistently designs precise, well-structured prompts with sufficient context, leading to highly relevant AI outputs. Low: Prompts are vague, lack context, or are poorly structured, resulting in irrelevant or unhelpful AI outputs.
Iterative Refinement & Problem Solving	Skill in analyzing AI responses and strategically modifying prompts to improve outcomes, overcome AI limitations, or explore different facets of a problem.	Think-alouds during refinement; Tracking prompt versions; Class discussion of refinement strategies.	PBL final product with documented PE process showing prompt evolution; Portfolio showcasing a series of refined prompts for a complex task.	High: Systematically analyzes AI output and iteratively refines prompts with clear purpose, demonstrating adaptability and effective problem-solving. Low: Makes minimal or random changes to prompts with little impact on output quality; struggles to adapt to AI limitations.
Critical Evaluation of AI Output	Capacity to critically assess AI-generated content for accuracy, relevance, bias, completeness, logical consistency, and potential "hallucinations."	Annotated AI outputs; Debates on AI information reliability; "Fact-check the AI" exercises.	Critical analysis essay of AI-generated text on a controversial topic; Project requiring integration and critique of AI-sourced information.	High: Consistently and thoroughly identifies potential biases, inaccuracies, and limitations in AI output; seeks multiple sources for verification and demonstrates nuanced judgment. Low: Accepts AI output at face value with little or no questioning or verification; fails to identify obvious errors or biases.
Ethical Awareness & Responsible Use	Understanding and application of ethical principles in AI interaction, including data privacy, academic integrity, intellectual property, and avoidance of harmful uses or perpetuation of bias.	Scenario-based discussions on AI ethics; Role-playing ethical dilemmas; Quizzes on school AI use policies.	Reflective statement on ethical considerations in a PE project; Presentation addressing ethical implications of an AI application.	High: Demonstrates a strong understanding of ethical issues, consistently applies ethical principles in AI use, and can articulate potential societal impacts. Low: Shows little awareness of ethical concerns; uses AI irresponsibly or without regard for academic integrity or potential harm.
Creative & Innovative Application	Ability to use PE imaginatively to explore new ideas, generate novel solutions, create original content, or apply AI in unconventional and effective ways.	Brainstorming sessions using AI as a partner; "What if" prompting exercises; Sharing novel uses of PE.	Creative project co-produced with AI (e.g., story, art, music); Innovative solution to a problem developed with AI assistance; Portfolio entry showcasing unique prompting strategies.	High: Uses PE to generate highly original ideas, solutions, or creative works; experiments with unconventional prompts leading to insightful or novel AI outputs. Low: Uses PE only for basic information retrieval or predefined tasks; shows little experimentation or creative exploration.

6 Navigating the Landscape: Ethical Considerations and Challenges in K-12 Prompt Engineering Education

6.1 Algorithmic Bias, Misinformation, and "Hallucinations"

A primary concern is the risk of AI systems perpetuating and even amplifying societal biases present in their training data. AI tools can also generate inaccurate information or "hallucinations"—outputs that appear plausible but are factually incorrect or nonsensical. [22] explicitly mentions "biases in source texts" and the creation of "false or misleading information" as key concerns. Algorithmic bias can lead to AI tools providing skewed perspectives, reinforcing stereotypes, or offering less challenging material to certain demographic groups, thereby hindering equitable academic progress[19].

To counter these risks, PE education must incorporate strategies for teaching students to critically evaluate AI outputs. This includes developing the ability to "verify the accuracy and reliability of information"[4] and "integrating lessons on AI ethics, bias detection and fact-checking" into the curriculum[19]. Students need to understand that AI is not an infallible oracle but a tool whose outputs require careful scrutiny. The challenge of AI-generated misinformation fundamentally alters the nature of information literacy. Traditional methods of evaluating human-authored sources, which often rely on established markers of credibility, are insufficient for AI-generated content that can appear authoritative yet be subtly biased or entirely fabricated[2]. This necessitates that PE literacy programs cultivate new heuristics for trust and verification, making the critical thinking component of PE[3] even more vital.

6.2 Data Privacy and Security

The use of AI tools in educational settings raises significant concerns about student data privacy and security[2]. AI systems often collect and process user data, and in a K-12 context, this involves sensitive information about students' learning patterns, queries, and personal details. There are potential risks of "data breaches, unauthorized access, and the misuse of this sensitive information"[30]. Parents and students harbor "significant concerns about risks associated with GenAI" and are calling for greater transparency[6].

It is imperative for schools and educational authorities to establish clear policies regarding the use of AI tools, ensuring compliance with data protection regulations and promoting responsible data sharing practices. Students also need to be educated about digital citizenship, including understanding what data is being collected, how it might be used, and how to protect their personal information when interacting with AI.

6.3 Student Agency, Equity, and Responsible AI Use

A delicate balance must be struck between leveraging AI to enhance learning and ensuring that it does not undermine student agency or lead to over-reliance. While AI can offer personalized feedback and support[2], an excessive dependence on AI tools "may weaken students' critical thinking and information evaluation skills"[4] and negatively impact "student autonomy and agency"[30]. The curriculum must actively address this tension by emphasizing AI as a tool to augment and support human intellect and creativity, not replace it.

Furthermore, ensuring "equitable access to AI technologies" and PE education is critical[2]. Disparities in access to devices, internet connectivity, or quality instruction can exacerbate existing educational inequities. PE education should foster a "human-centered mindset"[9], encouraging students to understand and assert their agency in relation to AI, and promote the ethical and responsible use of these powerful technologies, aligning with frameworks like UNESCO's which emphasize "A human-centred mindset" and "Ethics of AI"[18]. Ethical PE education is not merely about teaching a set of rules but about fostering critical ethical reasoning. Students need to understand the 'why' behind ethical guidelines to navigate novel situations that will inevitably arise as AI technology continues to evolve rapidly. This involves developing a deeper ethical framework that enables them to make informed judgments even when specific rules for new AI capabilities do not yet exist.

6.4 Academic Integrity and Authenticity of Student Work

The ability of GenAI to produce human-like text presents significant challenges to traditional notions of academic integrity and the authenticity of student work[2]. Concerns about the "inability to verify whether work was generated by AI"[2] are widespread. Studies show "inconsistencies among users in terms of what counts as cheating when using GenAI"[6], and student surveys reflect varied perspectives on this issue[34].

Addressing these challenges requires more than just AI detection software, which itself can be fallible and potentially biased[35]. Pedagogical approaches need to shift emphasis from solely evaluating the final product to also assessing the learning process, critical engagement with source material (including AI-generated content), and students' ability to thoughtfully integrate and cite information. Clear institutional policies on the acceptable use of AI in academic work are essential.

6.5 The Evolving Role of the Teacher

The integration of AI and PE into the classroom necessitates a shift in the teacher's role from being the primary "knowledge transmitter to learning facilitator," guide, and co-learner[4]. Teachers must be prepared to model ethical and critical AI use, guide students in navigating the complexities of AI-generated information, and foster a classroom environment where AI is used as a tool for inquiry and creation, rather than a shortcut.

Table 4: Ethical Challenges in K-12 Prompt Engineering Education and Proposed Mitigation Strategies

Ethical Challenge	**Description of Challenge in K-12 PE Context (drawing from [2])**	**Pedagogical Mitigation Strategies**	**Policy/School-Level Mitigation Strategies**
Algorithmic Bias	AI tools may reflect and amplify societal biases present in training data, leading to skewed information, stereotypes, or inequitable learning recommendations.[2]	Activities requiring students to critique AI outputs from diverse perspectives; Explicitly teaching about how training data can introduce bias; Comparing outputs from multiple AI tools.	Vet AI tools for bias mitigation features; Promote use of diverse datasets in AI education; Regular review of AI tool impact on different student groups.
Data Privacy & Security	Collection and use of sensitive student data by AI tools, risking breaches, unauthorized access, or misuse.[2]	Teaching digital citizenship, including data privacy awareness; Using AI tools in ways that minimize personal data input; Discussing AI tool privacy policies.	Clear school policies on approved, vetted AI tools; Student data anonymization where possible; Staff training on data protection with AI; Transparent communication with parents about AI data use.
Misinformation & "Hallucinations"	AI generating plausible but false or misleading information, requiring students to develop strong verification skills.[2]	Teaching critical evaluation and fact-checking skills specifically for AI-generated content; Emphasizing cross-referencing with reliable sources; "Red teaming" AI outputs to find errors.	Curating lists of reliable AI tools and information sources; Providing access to fact-checking tools and resources.
Over-Reliance & Diminished Agency	Students becoming overly dependent on AI for answers, potentially weakening their own critical thinking, problem-solving, and creative skills.[4]	Designing tasks that require AI as a collaborator, not a replacement for thought; Focusing on process and student reasoning; Emphasizing human skills AI cannot replicate.	Promoting a balanced approach to technology integration; School-wide discussions on the role of AI in learning; Encouraging tasks that require higher-order human cognition.
Academic Integrity	AI tools being used to generate assignments, leading to plagiarism and challenges in assessing authentic student learning.[2]	Redesigning assignments to focus on process, critical analysis of AI outputs, or unique applications; Teaching ethical AI use and proper citation of AI assistance; In-class discussions and reflections on AI-generated content.	Clear, updated academic integrity policies addressing AI use; Professional development for teachers on assessing work in an AI era; Fostering a culture of academic honesty.
Equitable Access	Disparities in student access to AI tools, reliable internet, or quality PE instruction, potentially widening achievement gaps.[2]	Utilizing free and accessible AI tools; Providing differentiated instruction and support for PE; Designing "unplugged" PE-related activities.	Ensuring provision of necessary devices and connectivity; Allocating resources for equitable AI tool access across schools; Targeted support for underserved student populations.

7 Empowering Educators: Professional Development for Effective Prompt Engineering Pedagogy

7.1 The Need for Teacher AI Literacy and PE Competence

Currently, many educators feel unprepared to effectively teach or utilize prompt engineering[5]. The "lack of frameworks that focus on leveraging GenAI in education settings leave many educators unprepared" to navigate this new terrain. This is not surprising, given the rapid pace of AI development. Teachers require more than just technical skills in using AI tools; they need robust pedagogical knowledge to effectively teach PE, integrate it meaningfully into their subject areas, and guide students through the associated ethical complexities[4]. As noted in [4], the teacher's role is shifting, "emphasizing the importance of professional basic knowledge and ethical education." There is a clear call for "educators to have robust professional learning" to meet these new demands[19]. This underscores that teacher professional development (PD) for PE must go beyond basic technical training on "how to prompt" to comprehensively encompass "how to teach prompting" and, crucially, "how to foster critical and ethical thinking about AI through prompting."

7.2 Essential Competencies for Teachers

Effective PE pedagogy requires teachers to develop a multifaceted set of competencies. This includes understanding AI fundamentals, such as a foundational knowledge of how GenAI and LLMs work, including their capabilities, underlying mechanisms (at a conceptual level), and inherent limitations[9]. Teachers need prompt engineering skills for proficiency in crafting clear, effective, and varied prompts for diverse educational purposes[1]. They must have pedagogical content knowledge (PCK) for PE to translate PE knowledge into effective teaching practices, including designing developmentally appropriate PE learning activities and integrating PE into various subject areas[8]. Ethical awareness and guidance are crucial, requiring a deep understanding of the ethical issues surrounding AI in education and the ability to guide students in using AI responsibly[8]. Teachers also need skills in the assessment of PE literacy, including knowledge of various formative and summative assessment strategies. Finally, they should develop the ability to use AI for professional tasks to enhance their own practice, such as for lesson planning or creating differentiated materials[2].

7.3 Frameworks for Teacher Professional Development

Several existing frameworks can inform the design of comprehensive PD programs for PE. The UNESCO AI Competency Framework for Teachers outlines key areas including developing a human-centered mindset, understanding ethics of AI, acquiring AI foundations knowledge, mastering AI pedagogy, and leveraging AI for professional development[21]. The AILit Framework (EC/OECD), with its domains of Engaging with AI, Creating with AI, Managing AI's actions, and Designing AI solutions, is highly relevant for structuring teacher competencies[8]. The IDEA Framework, introduced by Dr. Jiyeon Park, guides educators to Include essential components, Develop prompts using clear language, Evaluate outcomes and refine prompts, and Apply accountability[5]. The ISTE Standards for Educators (Learner, Leader, Citizen, Collaborator, Designer, Facilitator, Analyst) provide a broader context for technology integration, within which AI and PE competencies can be situated[25].

7.4 Models for Professional Development Delivery

Effective PD for PE should be ongoing, practical, and collaborative. Models can include workshops and online courses for foundational knowledge[19], Professional Learning Communities (PLCs) for collaboration, instructional coaching for individualized support, and action research projects for investigating impact. Crucially, PD should model the same student-centered, inquiry-based, and project-based approaches that teachers are expected to use. Instead of passive lectures, PD could involve teachers collaboratively designing PE-infused PBL units or developing ethical use guidelines for their schools. Such active learning experiences are more likely to build teacher confidence and lead to meaningful changes in classroom practice. A systemic failure to adequately prepare teachers will likely be the most significant bottleneck to realizing PE's potential. Existing inequities in PD access, such as urban districts being less likely to provide GenAI training[6], must also be addressed to ensure all teachers have the opportunity to develop these essential competencies.

8 Conclusion: Advancing Prompt Engineering Literacy for Future-Ready K-12 Learners

8.1 Recap of Key Arguments

This paper has underscored the critical imperative of establishing prompt engineering (PE) as a foundational 21st-century literacy within K-12 education. Moving beyond a narrow technical definition, PE has been conceptualized as a comprehensive literacy involving critical thinking, iterative refinement, creative problem-solving, and robust

Table 5: Essential Competencies for Teacher Professional Development in Prompt Engineering Pedagogy

Competency Domain	Specific Competencies/Skills within the domain	Alignment with Teacher Frameworks (e.g. [8])	Sample PD Activity/Focus
Foundational AI Knowledge	Understand core concepts of GenAI, LLMs, their capabilities, limitations, and societal impact.	UNESCO: AI Foundations; AILit: Engaging with AI; ISTE: Learner.	Workshop on "How LLMs Work (Conceptually)"; Interactive session on current AI trends and educational implications.
Prompt Engineering Proficiency	Master techniques for crafting, refining, and optimizing prompts for diverse educational tasks (for self and to model for students). Apply frameworks like IDEA.[5]	UNESCO: AI Applications; AILit: Creating with AI; ISTE: Designer.	Hands-on lab: "Advanced Prompting Techniques"; Collaborative prompt-a-thons to solve teaching challenges.
PE Pedagogical Skills	Design developmentally appropriate PE learning activities across K-12; Integrate PE into diverse subject areas; Scaffold PE instruction effectively; Facilitate student inquiry using AI.	UNESCO: AI Pedagogy; AILit: Creating with AI, Designing AI solutions; ISTE: Designer, Facilitator.	Collaborative curriculum mapping for PE integration; Micro-teaching sessions on PE lessons; Developing PBL units with PE components.
Ethical AI Pedagogy	Understand and teach AI ethics (bias, privacy, fairness, transparency, accountability); Guide students in responsible and critical AI use; Address academic integrity.	UNESCO: Ethics of AI, Human-centred Mindset; AILit: Engaging with AI, Managing AI's actions; ISTE: Citizen, Facilitator.	Workshop on analyzing AI tools for bias; Developing classroom guidelines for ethical AI use; Case study discussions on AI dilemmas in education.
PE Assessment Skills	Develop and use formative and summative assessments for PE literacy; Create and adapt rubrics for evaluating PE competencies.	UNESCO: AI Pedagogy; ISTE: Analyst.	Session on designing performance-based PE assessments; Collaborative rubric development workshop.
AI for Professional Productivity & Development	Leverage AI tools for lesson planning, differentiation, feedback generation, administrative tasks, and own lifelong learning.	UNESCO: AI for Professional Development; ISTE: Learner.	Showcase and practice with AI tools for educators (e.g., lesson planners, quiz generators); Setting personal AI learning goals.

ethical awareness. A curriculum framework, rooted in Backward Design principles and actualized through Project-Based Learning and Computational Thinking, has been proposed, outlining developmentally appropriate learning progressions from elementary through high school and emphasizing cross-curricular integration. Complementing this, a multi-dimensional assessment framework has been detailed, advocating for a blend of formative and summative strategies, supported by clear rubrics, to holistically evaluate PE competencies. Throughout this exploration, the centrality of addressing profound ethical considerations—such as algorithmic bias, data privacy, student agency, and academic integrity—has been paramount, alongside the unequivocal need for comprehensive professional development to empower educators in this evolving pedagogical landscape.

8.2 Recommendations for Stakeholders

The successful cultivation of PE literacy demands coordinated effort from all echelons of the education ecosystem.

Policymakers: It is recommended that policymakers champion the integration of PE literacy into national and regional curricula. This includes allocating funding for research into effective PE pedagogies, supporting the development of high-quality instructional resources, and investing substantially in teacher professional development programs.

Curriculum Developers: The onus is on curriculum developers to create adaptable, high-quality instructional materials, exemplar projects, and resources that align with the proposed frameworks. These materials should be designed to be accessible and cater to diverse learning needs.

School Leaders: School administrators play a crucial role in fostering a supportive environment for PE initiatives. This involves providing necessary technological resources, championing teacher training, establishing clear and ethical guidelines for AI use within the school community, and encouraging innovative pedagogical approaches.

Educators: Teachers are at the forefront of this transformation. It is recommended that educators embrace PE as an essential new literacy, actively engage in professional development opportunities, collaborate with peers to develop and share best practices, and critically reflect on their PE pedagogy.

Researchers: The academic community must continue to investigate the multifaceted aspects of PE in K-12 education. This includes rigorous research on the efficacy of different pedagogical approaches, the development and validation of robust assessment tools, deeper exploration of ethical implications, and studies focused on ensuring equitable implementation and outcomes for all student populations.

8.3 Future Research Directions

The field of PE in education is nascent and dynamic, necessitating ongoing inquiry. Key future research directions include longitudinal studies to assess the long-term impact of PE literacy on student learning outcomes and career readiness; the development and validation of standardized, yet flexible, PE assessment tools; comparative studies evaluating the effectiveness of different PE pedagogical models; research focused on strategies for the equitable implementation of PE education; and continuous investigation into the evolving nature of prompt engineering itself as AI models become more sophisticated, and how K-12 curricula can adapt to these advancements. The frameworks for curriculum, assessment, and professional development must be designed for adaptability and continuous improvement, incorporating ongoing research findings and responding proactively to the rapid evolution of AI technologies[2].

8.4 Concluding Vision

The integration of prompt engineering into K-12 education is more than an academic exercise; it is an investment in future societal resilience, innovation, and equity. By empowering K-12 students with the skills and ethical grounding to be critical, creative, and responsible users—and potentially shapers—of AI technology, we equip them not only for the demands of a rapidly changing world but also to contribute meaningfully to a future where human-AI collaboration can be harnessed for positive global change[21]. The goal is to cultivate a generation that can navigate the complexities of an AI-driven world with confidence, discernment, and a commitment to human-centered values, ensuring that AI serves humanity's best interests.

To Cite This Article Emily SONG. (2025). Prompt Engineering as a 21st-Century Literacy: A K-12 Curriculum Design and Assessment Framework. *Artificial Intelligence Education Studies*, *1*(2), 32–47. https://doi.org/10.6914/aiese.010203

Reference

[1] Clifford, J. (n.d.). *Beyond the Economic Textbook (Volume I): The ultimate resource for teaching high school economics through real-world applications and AI integration.* Magers & Quinn Booksellers. Retrieved June 12, 2025, from https://www.magersandquinn.com/product/BEYOND-THE-ECONOMIC-TEXTBK-(VO/27993590

[2] Sanchez, S. A., Williams, R., Egede, L., & Lipets, M. (2025). *Implementation of a generative AI assistant in K-12 education: The CyberScholar Initiative* [Preprint]. arXiv. https://arxiv.org/pdf/2502.19422

[3] Adhikari, A., Adhikari, S., & Shrestha, A. (2024). *A survey of techniques, key components, strategies, challenges, and student perspectives on prompt engineering for large language models (LLMs) in education* [Preprint]. ResearchGate. https://www.researchgate.net/publication/390313636_A_Survey_of_Techniques_Key_Components_Strategies_Challenges_and_Student_Perspectives_on_Prompt_Engineering_for_Large_Language_Models_LLMs_in_Education

[4] Yang, H., & Liu, Y. (2024). *The impact of generative artificial intelligence on university information literacy education: A systematic review from challenges to changes* [Preprint]. ResearchGate. https://www.researchgate.net/publication/389627457_The_Impact_of_Generative_Artificial_Intelligence_on_University_Information_Literacy_Education_A_Systematic_Review_from_Challenges_to_Changes

[5] Center for Innovation, Design, and Digital Learning. (n.d.). *CIDDL research and practice brief: Generative AI prompt engineering for educators.* Retrieved June 12, 2025, from https://ciddl.org/ciddl-research-and-practice-brief-generative-a

[6] AI for Education. (n.d.). *Studies related to generative AI in education.* Retrieved June 12, 2025, from https://www.aiforeducation.io/ai-resources/studies-related-to-generative-ai-in-education

[7] The University of Texas at Austin, Center for Teaching and Learning. (n.d.). *Generative AI in teaching and learning: Prompt design.* Retrieved June 12, 2025, from https://ctl.utexas.edu/generative-ai-teaching-and-learning-prompt-design

[8] Dondi, M. (2025, May 22). *Why AI literacy is now a core competency in education.* World Economic Forum. Retrieved June 12, 2025, from https://www.weforum.org/stories/2025/05/why-ai-literacy-is-now-a-core-competency-in-educ

[9] Asha, I. K. (2025). Empowering K-12 education with AI. In M. Khosrow-Pour (Ed.), *Advancing educational technologies through modern learning theories* (pp. 60 81). IGI Global. https://library.oapen.org/bitstream/handle/20.500.12657/95794/1/9781003498377_10.4324_9781003498377-4.pdf

[10] University of California Merced, Teaching Commons. (n.d.). *Backward's design: Start with the outcomes.* Retrieved June 12, 2025, from https://teach.ucmerced.edu/pedagogy-guides/backwards-design

[11] University of San Diego, Professional and Continuing Education. (n.d.). *3 basic steps of backward design lesson plans [+FAQs]*. Retrieved June 12, 2025, from https://pce.sandiego.edu/backward-design-in-education/

[12] Unrulr. (2024, May 22). *100 project-based learning ideas*. Retrieved June 12, 2025, from https://www.unrulr.com/post/100-project-based-learning-ideas

[13] T, S., & G, D. (2024). AI-enhanced project- based learning: Revolutionizing commerce education with generative AI. *Shanlax International Journal of Commerce*, *12*(S1), 31 35. https://www.researchgate.net/publication/389891094_AI-Enhanced_Project-_Based_Learning_Revolutionizing_Commerce_Education_With_Generative_AI

[14] Boss, S. (2024, February 21). *How students can use AI in project-based learning*. Edutopia. Retrieved June 12, 2025, from https://www.edutopia.org/article/how-students-use-ai-pbl-units/

[15] Wolpert-Gawron, H. (2015, November 10). *Project based learning: Assessment and other dirty words*. Teaching Channel. Retrieved June 12, 2025, from https://www.teachingchannel.com/k12-hub/blog/project-based-learning-assessment

[16] Sheldon, E. (2016, October 5). *Computational thinking across the curriculum*. Edutopia. Retrieved June 12, 2025, from https://www.edutopia.org/blog/computational-thinking-across-the-curriculum-eli-sheldon

[17] Ellipsis Education. (n.d.). *Computational thinking in elementary school*. Retrieved June 12, 2025, from https://ellipsiseducation.com/computational-thinking-elementary-school

[18] UNESCO. (2024, April 19). *AI competency framework for students*. Retrieved June 12, 2025, from https://www.unesco.org/en/articles/ai-competency-framework-students

[19] Guzman, I. (2024, March). Ethics and AI. *Leadership Magazine*. Retrieved June 12, 2025, from https://leadership.acsa.org/ethics-and-ai

[20] Teachers Pay Teachers. (n.d.). *PBL projects for middle school*. Retrieved June 12, 2025, from https://www.teacherspayteachers.com/browse?search=pbl%20projects%20for%20middle%20school

[21] UNESCO. (2024, November 18). *What you need to know about UNESCO's new AI competency frameworks for students and teachers*. Retrieved June 12, 2025, from https://www.unesco.org/en/articles/what-you-need-know-about-unescos-n

[22] AI for Social Good. (n.d.). *Home*. Retrieved June 12, 2025, from https://www.aiforsocialgood.org/

[23] Wang, J., Chen, T., Zhang, Y., & Chen, J. (2025). How generative AI enables an online project-based learning platform: An applied study of learning behavior analysis in undergraduate students. *Applied Sciences*, *15*(5), 2369. https://doi.org/10.3390/app15052369

[24] Emerald Publishing. (n.d.). *Artificial Intelligence in Education*. Retrieved June 12, 2025, from https://www.emeraldgrouppublishing.com/journal/aiie

[25] Toolify. (n.d.). *Mastering ISTE standards: A guide for educators using AI*. Retrieved June 12, 2025, from https://www.toolify.ai/ai-news/mastering-iste-standards-a-guide-for-educators-using-ai-3448007

[26] ISTE. (n.d.). *ISTE Standards*. Retrieved June 12, 2025, from https://iste.org/standards

[27] Learning Everest. (2023, November 29). *Exploring examples of formative assessment techniques*. Retrieved June 12, 2025, from https://www.learningeverest.com/formative-assessment-techniques/

[28] Edge Foundation. (n.d.). *Strategies to support PBL: Project walls, protocols, rubrics and 21st century skills*. Retrieved June 12, 2025, from https://www.edge.co.uk/practice/resources-for-teachers/steps-in-project-based-learning-expeditionary-pbl-and-el-strategies-protocols-rubrics/

[29] EDGEucating. (n.d.). *Project-based learning rubric template*. Retrieved June 12, 2025, from https://edgeucating.com/store/project-based-learning-rubric-template/

[30] Richardson, J., & Chtouki, Y. (2024). *The ethics of using AI in K-12 education: A systematic literature review* [Preprint]. ResearchGate. https://www.researchgate.net/publication/390363812_The_ethics_of_using_AI_in_K-12_education_a_systematic_literature_review

[31] Teachers Pay Teachers. (n.d.). *Collaboration rubrics*. Retrieved June 12, 2025, from https://www.teacherspayteachers.com/browse/free?search=collaboration%20rubrics

[32] Teachers Pay Teachers. (n.d.). *Rubrics for critical thinking*. Retrieved June 12, 2025, from https://www.teacherspayteachers.com/browse?search=rubrics%20for%20critical%20thinking

[33] North Salem Central School District. (2016). *Rubric for creative, divergent and critical convergent thinking*. Retrieved June 12, 2025, from https://ny50000167.schoolwires.net/cms/lib/NY50000167/Centricity/Domain/34/030316_NSalemCreatCritRubric.pdf

[34] Chan, C. K. Y. (2024). Student perspectives on the use of generative artificial intelligence technologies in higher education. *International Journal for Educational Integrity*, *20*(1). https://doi.org/10.1007/s40979-024-00153-3

[35] Abrams, Z. (2025, January 1). Classrooms are adapting to the use of artificial intelligence. *Monitor on Psychology*, *56*(1). https://www.apa.org/monitor/2025/01/trends-classrooms-artificial-intelligence

Editor *Changkui LI wtocom@gmail.com*