A methodological approach for applications of generative AI to support students and teachers

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Abstract

This paper presents a methodological exploration of the integration of Generative AI into computing education through prompt-based interaction. Rather than offering a comparative overview across diverse educational contexts, we focus on a series of in-depth qualitative investigations conducted in both secondary and higher education. Across scenarios ranging from computational thinking in schools to project-based learning in engineering, GenAI tools are treated not as automation engines, but as dialogic partners that scaffold reasoning, abstraction, and problem decomposition. Prompts are framed as epistemic artifacts that mediate iterative learning, reflection, and design. We examine how learners and educators interact with GenAI in real educational workflows—constructing prompts, interpreting responses, and developing strategies for refinement and evaluation. Activities include co-design of system architectures, debugging, documentation, and assessment validation. The findings emphasize the value of GenAI when integrated into human-centered pedagogical settings: not as a replacement for human cognition, but as a catalyst for deeper engagement and metacognitive development. This qualitative approach offers design principles for developing reflective, AI-supported learning environments, and points to future directions for research and practice.

Keywords

Generative AI, Prompt-based Learning, Human-AI Interaction, Computational Thinking, Project-Based Education, Reflective Practice, AI in Assessment, Qualitative Educational Research

1. Introduction

The rapid evolution of Generative AI (GenAI) is reshaping educational design and practice. While Large Language Models (LLMs) demonstrate strong capabilities in routine programming tasks, their integration into educational workflows poses new challenges, both pedagogical and ethical [1]. These tools raise concerns about plagiarism and superficial learning, but also invite a broader rethinking of assessment formats and learning strategies in digital education.

Several recent studies have sought to define competence frameworks and institutional strategies for GenAI adoption [2, 3, 4]. In contrast, this paper adopts a situated and exploratory perspective, rooted in real educational interactions and attentive to the micro-dynamics of human-AI dialogue. Rather than offering a comparative overview across roles or institutions, we focus on a series of in-depth qualitative investigations that emphasize learning dynamics, prompt refinement, and epistemic scaffolding through prompt-based interaction.

At the core of our methodology is the concept of prompt-based learning, understood not as a mechanical interface tactic, but as a structured and iterative process. Prompts are treated as epistemic artifacts that enable learners to externalize, refine, and evaluate their reasoning in dialogue with generative systems. This approach aligns with recent research that positions iterative prompting as a lever for developing computational reasoning, abstraction, and metacognitive awareness [1, 5].

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The methodology has been applied and refined in a series of experimental activities conducted at the University of Genoa, including:

- scaffolded prompt-driven exercises for introducing computational thinking in schools with particular attention to problem solving strategies such as problem decomposition;
- iterative project-based learning activities in engineering courses, where GenAI is integrated across the full development lifecycle;
- exploratory simulations using GenAI to rethink the structure, robustness, and diagnostic value of assessment formats.

These interventions share a common epistemological stance: GenAI should not be treated as a black box that delivers solutions, but as a dialogic environment that elicits and shapes human reasoning. This view is grounded in a constructivist and interactional paradigm, where cognition is distributed across human and machine actors, and learning emerges through reflective, iterative exchange.

2. Design Thinking with GenAI: Collaborative Modeling and Iterative Development in an Embedded Systems Course

In the Master's level course *Software Architecture for Embedded Systems*, part of the Mechatronics Engineering program at the University of Genoa, GenAI was not introduced as an external tool, but as an embedded cognitive partner in all phases of system development—from architectural ideation to implementation and project management.

This educational experiment was guided by the hypothesis that GenAI, when methodologically integrated, could support not only the acceleration of development cycles, but also a deeper internalization of software architecture principles and a more reflective design practice. To this end, students engaged in collaborative workflows where LLMs were employed through structured prompting strategies at each step of the design process.

The course was structured into two interconnected phases. The first introduced foundational concepts—IoT architectures, UML modeling, state machines, and communication protocols—while gradually familiarizing students with prompt engineering techniques tailored for architectural exploration. The second phase involved the realization of a working prototype on an embedded platform (e.g., Arduino-based systems), where GenAI served as a prompt-responsive co-designer for the creation of code, diagrams, control logic, and documentation. Rather than focusing on tool performance, the course design emphasized the capacity of GenAI to support:

- distributed reasoning between human and machine agents;
- iterative refinement through natural language interaction;
- documentation as a process of self-explanation;
- responsibility and agency in validating and selecting AI-generated artifacts.

The most visible impact of this approach was a reduction in time-to-prototype: all student teams delivered functional systems with autonomous navigation or SLAM capabilities within a one-month development window. Compared to prior editions of the course, this represented both a productivity gain and a notable shift in how design tasks were conceptualized and scaffolded.

Collaborative Planning and Risk-Aware Development. An innovative aspect of the course was the integration of GenAI into project management practices, aligned with the evolving guidance of the Project Management Institute (PMI) and the forthcoming PMBOK 8 [6]. Beyond supporting software development, LLMs were engaged in the design of Work Breakdown Structures (WBS), the drafting of Gantt charts, and the simulation of project risks.

Prompting was used not only to generate artefacts, but to engage in planning dialogue: students asked LLMs to estimate time and resources, validate dependencies, and reflect on the completeness of task decomposition. Risk registers were co-constructed with AI systems based on given scenarios, allowing students to anticipate failures and develop mitigation strategies.

This dual use—technical and managerial—reinforced the idea that GenAI could be integrated into a holistic design culture, where reasoning about the problem space and reasoning about the project timeline are two sides of the same educational process [7].

Pedagogical Implications: From Automation to Shared Cognition. Rather than treating GenAI as an automation tool, the course embraced an epistemological model based on distributed cognition. Students were prompted to document not only their design choices, but the evolution of their dialogue with the LLM—recording failed prompts, reformulations, and justifications for accepting or rejecting AI-generated output. This process fostered a form of reflective prompting, in which the AI acted as a cognitive partner whose suggestions had to be critically evaluated, validated, and integrated within a coherent architectural vision. Students retained responsibility for system-level decisions, while developing a more nuanced understanding of modularity, responsibility, and iteration.

Early outcomes showed improved engagement, faster convergence on viable solutions, and richer design discussions. The process also made room for self-awareness: students began to question the limits of the AI, recognize patterns in their own reasoning, and become more intentional in their prompts. In this sense, the LLM was not just a generator of content, but a *mirror* of the student's evolving design mindset. To further analyze the cognitive and organizational functions played by GenAI in this educational setting, we mapped the observed activities onto the seven AI application patterns identified by the PMI. Table 1 illustrates this alignment, highlighting how GenAI mediated design, documentation, error detection, personalization, and planning across multiple dimensions of the course.

AI Pattern (PMI)	Pattern Description	Application in Educational Context
Recognition	Identifying and classifying objects or structures (e.g., images, diagrams)	AI-generated UML diagrams (Use Case, Class, State) via PlantUML, aiding system modeling and documentation
Conversation and Human Interaction	Natural language exchange between human and AI	Prompt-based interaction for code generation, debugging, architecture negotiation, and tutoring dialogue
Goal-Driven Systems	AI systems optimize toward a defined objective via iterative feedback	Students use GenAI to co-design subsystems (e.g., telemetry or SLAM) by refining prompts and AI-generated plans
Pattern and Anomaly Detection	Identifying inconsistencies, faults, or outliers in data or process	AI-assisted debugging via error analysis and log interpretation, helping detect anomalies in sensor data or control flows
Predictive Analytics and Directions	Using past behavior or data to anticipate future outcomes or choices	Project planning and risk mitigation simulations using GenAI, including effort estimation and timeline projection
Document Management	Creation, organization, and handling of structured content	Automated generation of system documentation, design logs, WBS charts, and class reports through iterative prompting
Hyper-Personalization	Tailoring responses or content to individual users or needs	Adaptive feedback based on prompt refinement, allowing students with different coding skills to obtain targeted support

Table 1: Mapping the Seven AI Patterns to Educational Use Cases in Embedded Systems Design

These findings suggest that GenAI, when integrated into project-based learning environments through methodical prompting strategies, can act as both catalyst and scaffold. In the next section, we explore how this approach has been adapted to foundational learning contexts, where students begin developing computational thinking skills and problem decomposition strategies through AI-mediated interaction.

Decompose the current task into the smallest possible number of subtasks (usually two or three). You must produce at least two subtasks and you can produce up to five subtasks. For each subtask, provide a name as well as a description, similar to the one provided for the main problem. Each subtask must be simpler to solve than the main task. A subtask of a given task, should not include any elements of other tasks at the same level of decomposition. Ensure that there are no missing steps: i.e. the sum of all subtasks solves the entire task.

Figure 1: Prompt for task decomposition.

3. Scaffolding Computational Thinking through Generative Interaction in School Contexts

While advanced technical courses allow for full integration of GenAI into system-level design workflows, a different set of challenges emerges in foundational learning contexts—especially when working with students with limited programming experience. In this setting, the primary goal is not the optimization of technical solutions, but the development of core problem-solving skills such as abstraction, decomposition, and iterative reasoning. The ability to decompose and represent problems aligns with the core principles of computational thinking as formulated by Wing [8], and can be scaffolded through prompt interaction as shown in recent frameworks [9].

In our intervention with high school students, we designed a prompt-based learning environment where GenAI was used not to provide final answers, but to support the articulation and refinement of computational questions. Students were presented with open-ended problems and asked to "teach" the AI what the solution strategy should look like, using natural language to decompose the task, propose steps, and identify conditions (see, e.g., the prompt in Fig. 1). This approach is consistent with recent work on using LLMs to scaffold next-step thinking in introductory programming [10].

The focus of the activity was twofold: to make explicit the cognitive process of problem analysis through dialogue with the AI; to support metacognitive awareness by having students reflect on the completeness, clarity, and logic of their own instructions. This pedagogical design follows the principles of prompt-based learning as theorized in recent work [1], where the prompt itself becomes an object of learning—iteratively refined, tested, and evaluated. It also echoes findings in co-design-based project learning [5], where the dialogic nature of the interaction fosters student agency and critical ownership.

Students engaged with the AI not as a source of solutions, but as a responsive canvas: when the AI failed to produce meaningful output, students had to rethink how they had structured the prompt. This process encouraged the development of transferable skills such as precision in formulation, awareness of edge cases, and logical sequencing.

Although no formal assessment was conducted in this phase, observation and informal interviews revealed a marked shift in how students approached problems: from passively seeking an answer to actively constructing an explanation that the AI could understand. This inversion—designing the reasoning before observing the output—is at the core of the educational philosophy behind our approach.

In this sense, GenAI acts as a cognitive partner that amplifies student reflection and fosters the internalization of computational concepts through socially distributed dialogue. Preliminary evidence from other studies also suggests that GenAI use can impact motivation and computational thinking skills [11].

4. Exploring Assessment with GenAI: A Turing Test Approach

One of the most debated consequences of the introduction of GenAI in education is the need to rethink traditional formats of assessment. In particular, the widespread use of tools like ChatGPT raises questions about the validity, originality, and diagnostic function of written exams in computing disciplines.

In a set of exploratory experiments conducted at the University of Genoa, we investigated how generative AI tools perform when asked to solve real exam tasks from the first-year course in Computer Architecture, part of the Bachelor in Computer Science program. The exam includes a diverse set of tasks: theoretical questions, circuit design, assembly-level programming in RISC-V, and reasoning about the behavior of concurrent programs written in pseudocode.

Several studies have explored both opportunities and challenges in using ChatGPT for learning and assessment in undergraduate computer science [12]. Our approach was intentionally non-interactive and low-intervention: we submitted the exam tasks to GenAI tools using minimal prompt engineering, and compared the resulting answers with those of actual students. The objective was not to test the models per se, but to reflect on: Which kinds of tasks are easily solvable by GenAI tools under minimal prompting; Where GenAI answers reflect common student misconceptions; How exam design might need to evolve in light of these capabilities and limitations.

The results showed that tools such as ChatGPT performed well on knowledge-based questions (which make up around 77% of the total score), but less convincingly on comprehension and analysis tasks as defined in Bloom's taxonomy [13]. For example, in questions about the behavior of multithreading programs, ChatGPT often reproduced typical misconceptions found in weaker student responses,s, such as misunderstandings about race conditions, deadlocks, or terminatioproperties -phenomenaena already observin the in the pedagogical literature [14].

To broaden the perspective, we also tested Claude, Gemini, and Mistral on the same open questions. Although some of their answers included more sophisticated elements, such as examples of thread interleaving and asynchronous behavior, most responses remained vague or overly generic when applied to concrete program logic. This reinforced the need for nuanced, prompt refinement and expert validation.

Rather than drawing strong conclusions about model performance, we interpret these findings as a stimulus for rethinking exam and assignment design. GenAI can serve as a diagnostic mirror that helps educators identify which types of questions no longer discriminate effectively between deep understanding and surface-level reproduction. It can also act as a tool for validating assessments, exposing assumptions and ambiguities that may remain hidden in traditional grading practices.

These experiments are still in a preliminary and qualitative stage, but point toward a broader methodological question: How can we design assessments that are resilient to automation, yet supportive of reasoning, explanation, and authentic demonstration of skill?

5. Conclusion

This paper presents a methodological exploration of how GenAI can be meaningfully integrated into computing education through prompt-based interaction. Rather than adopting a comparative or policy-driven lens, our approach is grounded in situated qualitative observations of real educational experiences, ranging from computational thinking in schools to advanced design tasks in engineering courses and assessment practices in university settings.

Across these scenarios, GenAI tools were not introduced as automation engines or content providers, but as dialogic partners in learning. The prompts were treated as epistemic artifacts: iterative tools that enabled students and teachers to externalize, refine, and critically assess their reasoning processes. This emphasis on structured prompting and reflective participation led to richer problem decomposition, increased student agency, and deeper cognitive involvement.

Our work is grounded in context-sensitive, qualitative inquiry that intentionally diverges from broader systemic models aiming to standardize GenAI integration through certification, policy, or curriculum planning. Rather than defining what learners or educators should know about AI, we examined what they could co-construct with it—when the interaction is grounded in authentic tasks, iterative exploration, and human judgment.

The case-based methodology adopted here invites educators and researchers to pay closer attention to the fine-grained interactions that occur between humans and generative systems. Understanding how GenAI is perceived and used by both students and instructors is essential to this pedagogical rethinking. Students and instructors have expressed both enthusiasm and skepticism regarding the role of GenAI in computing education, reflecting a wide spectrum of perceptions about its pedagogical value [15].

Although the results presented are preliminary and grounded in qualitative reflection, they provide

design principles and pedagogical insights for the construction of GenAI-supported learning environments. Future work will aim to formalize this methodology, develop mixed-method evaluation frameworks, and examine how prompt-based learning evolves across disciplines, educational levels, and institutional settings.

Ultimately, integrating GenAI into education is not simply a matter of access or efficiency, but of rethinking how knowledge is constructed, how skills are built, and how agency is distributed between humans and machines in the learning process.

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT in order to: Paraphrase and reword, Improve writing style, Grammar and spelling check. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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