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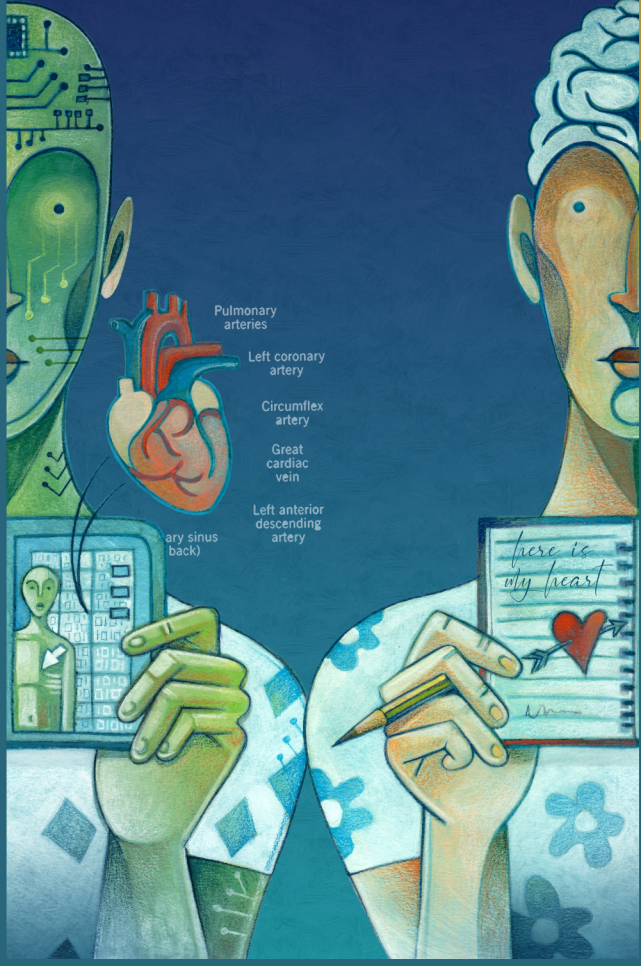
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18 November 2026

Lorella Giannandrea
Francesca Gratani
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VALUTAZIONE E INTELLIGENZA ARTIFICIALE

PROSPETTIVE DIDATTICHE, ETICHE E METODOLOGICHE

ATTI DEL CONVEGNO PRIN "AI&F - ARTIFICIAL INTELLIGENCE & FEEDBACK FOR EFFECTIVE LEARNING".
22 E 23 GENNAIO 2026
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II.7
From Challenge to Opportunity: Critical Use of GenAI in Mathematical Foundations for Architecture Students

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Abstract

This paper presents an exploratory teaching experience integrating Generative AI (GenAI) into mathematical foundations courses for architecture students. The intervention transformed GenAI from a perceived threat into a pedagogical opportunity through a "discuss the screen" methodology implemented across four sessions during a semester. Students developed critical thinking skills by comparing their solutions with GenAI outputs, addressing four pedagogical dimensions: disciplinary (improving mathematical understanding), digital (promoting conscious GenAI use), andragogical (enhancing motivation), and metacognitive (developing transversal reflection skills). Observations from final exams and classroom interactions suggest increased metacognitive awareness, evidenced by more explanatory comments and sustained engagement. This exploratory experience demonstrates how thoughtful integration of GenAI can enhance relational understanding of mathematics while developing critical thinking competencies, offering initial insights that warrant further systematic investigation.

Keywords: Generative Artificial Intelligence; Mathematics Education; Critical Thinking; Metacognition; Architecture students.

Questo contributo presenta un'esperienza didattica esplorativa di integrazione dell'Intelligenza Artificiale Generativa (GenAI) nei corsi di fondamenti matematici per studenti di architettura. L'intervento ha trasformato la GenAI da potenziale minaccia percepita a opportunità pedagogica attraverso una metodologia di "discuss the screen", implementata in quattro sessioni nel corso di un semestre. Gli studenti hanno sviluppato capacità di pensiero critico confrontando le pro-

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prie soluzioni con gli output della GenAI, lavorando su quattro dimensioni pedagogiche: disciplinare (miglioramento della comprensione matematica), digitale (promozione di un uso consapevole della GenAI), andragogica (potenziamento della motivazione), e metacognitiva (sviluppo di competenze trasversali di riflessione). Le osservazioni emerse dagli esami finali e dalle interazioni in aula suggeriscono un aumento della consapevolezza metacognitiva, evidenziato da un maggior numero di commenti esplicativi e da un impegno sostenuto nel corso. Questa esperienza esplorativa mostra come un'integrazione critica e intenzionale della GenAI possa favorire una comprensione relazionale della matematica e lo sviluppo di competenze di pensiero critico, offrendo prime evidenze che richiedono ulteriori indagini sistematiche.

Parole Chiave: Intelligenza Artificiale Generativa; didattica della matematica; pensiero critico; metacognizione; studenti di architettura.

1. Introduction

The advent of Generative Artificial Intelligence (GenAI) has profoundly altered the educational landscape, particularly in foundational mathematics courses. Tools like ChatGPT and Claude can solve mathematical exercises instantaneously, creating an illusion that computational skills can be outsourced without understanding the underlying processes. This phenomenon is especially critical in non-characterizing courses, such as mathematical foundations for architecture students, where the perception of utility is already fragile.

At Politecnico di Torino, the course "Istituzioni di Matematiche" (Mathematical Foundations) represents a mandatory 8 ECTS requirement for first-year architecture students. Traditionally perceived as an obstacle rather than an opportunity, this course faces the additional challenge of students questioning its relevance in an era where AI can perform calculations. However, this challenge can be transformed into a pedagogical opportunity by critically integrating GenAI into the learning process.

This paper presents an exploratory educational intervention that reframes GenAI from a tool that threatens to make mathematical skills obsolete into a pedagogical instrument that enhances critical thinking, metacognitive awareness, and relational understanding of mathematics. The approach is grounded in Skemp's distinction between instrumental and relational understanding (Skemp, 1976), combined with scaffolding theory (Wood, Bruner, & Ross, 1976) and a four-dimensional pedagogical framework addressing disciplinary, digital, andragogical, and metacognitive competencies.

This work documents a teaching experience rather than a controlled empirical study. The observations presented emerge from classroom practice and qualitative assessment of student engagement and exam performance. While these initial findings are promising, they represent preliminary evidence requiring further systematic investigation with rigorous research methodology.

2. Theoretical Framework

Skemp (1976) distinguished between two types of mathematical understanding: instrumental understanding ("knowing how to do something") and relational understanding ("knowing both what to do and why"). In traditional mathematics education, particularly in service courses for non-mathematical programs, there is often an overemphasis on instrumental understanding, where students learn algorithms and procedures without grasping the conceptual foundations.

GenAI tools excel at instrumental tasks but fundamentally lack relational understanding. This creates a pedagogical paradox: if we teach mathematics purely instrumentally, we are teaching students to do what machines can already do better. However, if we use GenAI's limitations as a teaching tool, we can highlight the irreplaceable value of relational understanding.

The pedagogical approach draws significantly on Vygotsky's concept of scaffolding and the Zone of Proximal Development (ZPD). Scaffolding refers to the temporary support structures that enable learners to accomplish tasks they cannot yet perform independently (Wood, Bruner & Ross, 1976). In traditional mathematics education, scaffolding typically involves instructor guidance, worked examples, or peer collaboration.

The "discuss the screen" methodology introduces a novel form of scaffolding: using GenAI's imperfect outputs as cognitive scaffolds. Unlike traditional scaffolding where the support is more knowledgeable, GenAI provides a different kind of support: a comparator that forces explicit articulation of reasoning. Students work within their ZPD as they evaluate outputs that are sometimes correct, sometimes subtly wrong, requiring them to stretch beyond their current independent capability while remaining within reach through collaborative discussion. This approach aligns with Wood et al.'s (1976) scaffolding functions: reducing degrees of freedom by focusing attention on specific aspects of solutions, maintaining direction toward the goal, highlighting critical features, and controlling frustration. The gradual release of responsibility, with progressive fading of instructional support as learners gain competence, is characteristic of

effective scaffolding in cognitive apprenticeship models (Collins, Brown & Newman, 1989).

Secondly, the metacognition (defined as the awareness and regulation of one's own thinking processes) is crucial for deep mathematical learning (Schoenfeld, 1992). When students must articulate their reasoning, identify errors, and justify their solutions, they develop metacognitive skills that transcend specific mathematical content. The presence of GenAI creates authentic situations requiring students to explain their thinking explicitly.

3. Context and Methodology

The intervention took place during the 2024/25 academic year in "Istituzioni di Matematiche", a first-semester course for architecture students at Politecnico di Torino. The course comprised approximately 150 students with heterogeneous mathematical backgrounds, typical of architecture programs. The course content includes foundational mathematical topics often perceived as disconnected from architectural practice such as linear algebra, differential calculus, and integral calculus. The course follows a traditional structure with lectures delivered by the course holder (Prof. De Gregorio) and exercise sessions conducted by the author.

The pedagogical intervention centered on a methodology termed "discuss the screen", implemented during exercise sessions. Over 12 exercise sessions throughout the semester, four sessions incorporated this approach (approximately one every three sessions). The methodology follows a structured cycle:

Parallel Problem-Solving: Students receive an exercise to solve individually or in small groups with nearby classmates. Simultaneously, the same exercise is input into GenAI tools (primarily the free version of ChatGPT, with occasional verification using the paid version of Claude).

Individual/Collaborative Work: Students work on the problem for several minutes, applying their understanding and discussing approaches with peers.

Comparative Presentation: The instructor projects the GenAI solution on screen, initiating collective analysis. Students compare their solutions with the GenAI output.

Critical Discussion: When discrepancies emerge, the class engages in dialogue to identify who is correct and why. The instructor facilitates discussion without immediately revealing the answer, encouraging students to justify their reasoning.

Verification and Reflection: The class collectively decides on a follow-up

prompt to deepen the analysis. Critical reading continues iteratively until reaching consensus between student solutions and AI outputs. In some cases, the same exercise is presented using multiple LLM, repeating the cycle from point 3 to stimulate comparative analysis across different AI tools.

Exercises were deliberately chosen from standard course topics: determinants of 4×4 matrices, rank calculations for 4×3 matrices, solutions to linear systems, limits, and calculation of areas between curves. These exercises are procedurally complex enough that both students and GenAI can make errors, creating authentic opportunities for critical analysis. Prompts to GenAI were intentionally simple, mirroring how students typically interact with these tools. Examples include: "det of this 4x4 matrix [matrix data]" or "Tell me the solution of this linear system [system data]".

This authenticity was crucial, using sophisticated prompting techniques would have created a false scenario disconnected from students' actual GenAI usage.

The intervention followed the Safe AI in Education Manifesto principle (Alier Forment et al., 2024). Students did not directly use GenAI with personal accounts; all interactions occurred through the instructor's projected screen. This approach addressed privacy (no student data processed), equity (equal access regardless of resources), transparency (students informed about AI versions used), and critical distance (encouraging collective analysis rather than individual dependency).

Finally, the intervention was designed around four interconnected dimensions:

1. Disciplinary: Improving mathematical understanding through problem-solving and error analysis;
2. Digital: Promoting conscious, critical use of GenAI tools;
3. Andragogical / Pedagogical: Enhancing internal motivation and self-efficacy;
4. Metacognitive: Developing transversal reflection and self-regulation skills.

4. Implementation and Results

The first "discuss the screen" session generated considerable surprise. Many students had assumed GenAI tools were infallible for mathematical calculations. When ChatGPT produced a determinant value different from many students' calculations, the initial reaction was confusion. Rather than immediately reveal-

ing the correct answer, the instructor facilitated discussion: "How did you arrive at your answer? Can you explain each step?" Students began articulating their reasoning, identifying potential sign errors, transposition mistakes, or computational errors.

Importantly, GenAI did not always produce errors. In several cases, the AI's solution was correct, while some students had made mistakes. This proved equally valuable pedagogically: when there was no convergence within the class, collective reasoning helped identify errors made by some students. These instances reinforced correct problem-solving approaches and demonstrated that the methodology served not only to critique AI but to develop mutual learning within the student community.

Following the initial session, the instructor provided a simplified explanation of how Large Language Models function—predicting likely tokens based on statistical patterns rather than "understanding" mathematics. This demystification helped students appreciate both capabilities and fundamental limitations of GenAI. Students began to recognize that GenAI's errors weren't random failures but systematic limitations stemming from its statistical nature.

Subsequent sessions showed evolving sophistication in students' critical analysis. Initially, students identified primarily computational errors, like incorrect arithmetic in determinant expansions, sign errors in matrix operations, or mistakes in Gaussian elimination steps and limit calculations. Over time, students began identifying higher-level conceptual errors. For instance, when GenAI occasionally generated explanations suggesting "a matrix can have two different determinants", students recognized the conceptual impossibility. Similarly, when calculating the area bounded by a curve, GenAI sometimes directly computed the definite integral without checking the sign of the function, thus returning the signed area rather than the actual geometric area; a subtle but important distinction that requires proper setup of the definite integral. This shift from detecting computational mistakes to identifying logical and methodological inconsistencies represents significant cognitive development.

Students progressively developed *dialogical mathematical competence:* the ability to articulate mathematical reasoning clearly and precisely. One student's reflection captured this: "Explaining to someone who doesn't know but gives the impression of knowing is very complex". This observation reveals deep metacognitive awareness. Unlike explaining to an instructor or peer, explaining to GenAI requires assuming nothing and making all reasoning explicit. Throughout the semester, the instructor consistently emphasized this principle of explicit communication, and GenAI sessions provided concrete practice.

The most striking outcome appeared in final exam papers. Compared to pre-

vious years, there was a noticeable overall increase in explanatory comments between mathematical steps. Students wrote annotations like "applying linearity property", "since the determinant is zero, the system has infinite solutions", or "checking the rank condition before proceeding". These comments indicate metacognitive awareness with students monitoring their own reasoning and making implicit knowledge explicit.

Student engagement remained high throughout the semester. The first exam session saw higher attendance than in previous years, suggesting students actively followed the course. Despite increased participation, the pass rate remained consistent with previous first sessions, meaning that, in absolute numbers, more students successfully passed. Notably, this occurred despite the exam being scheduled one week earlier than usual, suggesting students were better prepared and more confident.

Students developed genuine critical thinking skills regarding GenAI outputs. The types of errors students learned to identify included computational errors (arithmetic mistakes, sign errors, transposition errors), procedural errors (incorrect application of algorithms, skipped steps), and conceptual errors (logically impossible statements, misunderstanding of mathematical properties). This progression of critical thinking capabilities aligns with Bloom's taxonomy (Bloom, 1956), moving from remembering and applying procedures to analyzing, evaluating, and creating explanations of mathematical reasoning. The intervention positively impacted motivation and self-efficacy. By demonstrating that they could identify errors that sophisticated AI made, students gained confidence in their own mathematical judgment. The collaborative nature of sessions created a supportive learning environment where errors were treated as learning opportunities rather than failures.

5. Discussion

This exploratory experience demonstrates that GenAI, when thoughtfully integrated, need not undermine mathematical education. Rather than pretending GenAI doesn't exist or prohibiting its use, the intervention embraced its presence while highlighting its limitations. The key pedagogical move was shifting from "AI as solution provider" to "AI as fallible collaborator requiring supervision". These reframing positions human mathematical understanding as essential rather than obsolete.

Skemp's framework proved particularly valuable for analyzing the pedagogical dynamics. GenAI's instrumental competence without relational understand-

ing created perfect teaching scenarios. When ChatGPT correctly applied cofactor expansion but made a sign error, it demonstrated instrumental understanding's insufficiency. When it generated conceptually impossible explanations, it revealed the absence of relational understanding. Students, by contrast, were developing both forms of understanding simultaneously.

The "discuss the screen" methodology exemplifies an innovative application of scaffolding theory. Rather than providing direct instructional support, the approach uses GenAI outputs as cognitive scaffolds that prompt metacognitive engagement. Key features include:

– structured comparison: presenting parallel solutions reduces self-assessment complexity,
– progressive complexity: gradual progression from computational to conceptual errors,
– collaborative support: whole-class discussion provides peer scaffolding,
– fading support: instructor interventions become less directive over time, and
– metacognitive prompting: requirement to explain "why" and "how".

GenAI serves as "provocative scaffolding", that is, it doesn't always provide correct support but rather provokes cognitive engagement through its fallibility.

The methodology presents several challenges. Time management is critical because facilitating discussion cannot be rushed, requiring a careful balance between content coverage and depth of engagement. Instructor improvisation is demanding due to the unpredictability of GenAI outputs, requiring deep content knowledge and pedagogical agility. Assessment alignment requires rethinking, trying to reward metacognitive competencies alongside correct answers. Scalability considerations are important: the approach was designed for 150 students with a variety of backgrounds, and it may require adaptation for much homogeneous classes. This study has significant limitations that must be acknowledged. The lack of systematic assessment means no pre/post measures of metacognitive skills were administered and suggests directions for future research. The absence of a control group makes it impossible to isolate the specific contribution of the "discuss the screen" methodology. Limited longitudinal tracking means long-term impact remains unknown. The observational rather than empirical approach reflects informed professional judgment rather than rigorous data collection. Multiple confounding variables could explain the observations.

6. Conclusion

This educational experience demonstrates that GenAI can be transformed into a powerful pedagogical tool for developing critical thinking and relational understanding. The "discuss the screen" methodology created authentic learning situations where students developed metacognitive awareness, dialogical competence, and genuine mathematical judgment.

Key success factors included treating GenAI outputs as fallible rather than authoritative, creating collaborative environments where errors are learning opportunities, emphasizing the irreplaceable value of human understanding, consistently requiring articulation of mathematical reasoning, maintaining ethical transparency, and leveraging scaffolding principles.

The intervention addressed multiple competency dimensions simultaneously preparing students not only to pass mathematics exams but to function as critical, reflective professionals in an AI-augmented world. As GenAI tools become increasingly sophisticated and ubiquitous, education must evolve beyond simply transmitting knowledge or skills that machines can replicate. Instead, we must cultivate distinctively human capacities: critical judgment, metacognitive awareness, creative problem-solving, and the ability to evaluate and contextualize information from any source.

This exploratory experience in mathematical foundations for architecture students offers one model for that evolution, demonstrating that the challenge of GenAI can indeed become an opportunity for deeper, more meaningful learning. However, substantial empirical research remains necessary to validate these preliminary observations and develop evidence-based practices. The approach is currently being extended during the 2025/26 academic year to other service mathematics courses, working across different learning moments beyond exercise sessions and integrating discipline-specific AI tools to further explore how GenAI can enhance mathematical education across diverse student populations.

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