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Strengthening Foundations in Electric Circuit Analysis through AI-Generated Analogies, Real-Life Examples, and Storytelling Pedagogy

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Abstract

Teaching electric circuit analysis to first-year engineering students is challenging due to the abstract nature of its concepts, which often lack immediate real-world connections. This paper describes an effective pedagogical practice that integrates artificial intelligence (AI)-generated analogies, real-life examples, and storytelling to simplify foundational ideas such as resistance, inductance, capacitance, and circuit theorems. Using ChatGPT, customized analogies and narratives were generated and embedded into lectures, offering students relatable and memorable pathways to conceptual understanding. The practice also incorporated historical scientific stories, such as the War of Currents and Faraday's discovery of induction, to contextualize theoretical content within technological and societal development. Quantitative evidence from internal assessments demonstrated a significant improvement of 14% in conceptual test scores compared to the previous group, along with higher student engagement levels documented through a structured perception survey (n = 43 out of 65). The approach is positioned as a practical and replicable enhancement of traditional pedagogy through AI assistance. Implementation details, prompts, workflow, lesson plans, and assessment rubrics are provided to support replication by other instructors. The practice demonstrates how AI tools, when used judiciously and pedagogically aligned, can strengthen foundational learning in engineering education.

Keywords: **AI-assisted teaching; analogies; storytelling pedagogy; circuit analysis; engineering education**

JETLP Category**— Practice**

1. Introduction

Electric Circuit Analysis is a fundamental and foundational course for first-year Electrical Engineering students, yet its highly abstract concepts—such as resistance, inductance, and capacitance—pose a significant conceptual barrier [1]. These core circuit ideas are often invisible and lack immediate, intuitive real-world connections, making them challenging for novices to visualize and internalize [2]. Traditional, math-heavy lecture-based instruction, which relies on passive information transfer, frequently fails to bridge the gap between theoretical models and experiential learning, leading to common student misconceptions and contributing to subsequent struggles in advanced coursework [3, 4].

The urgency for pedagogical innovation stems from the need to move beyond rote memorization and foster genuine conceptual clarity and critical thinking [5]. This paper proposes a novel instructional practice that integrates the cognitive power of analogical reasoning with the narrative depth of storytelling, significantly enhanced by Artificial Intelligence (AI) assistance [6]. Analogical reasoning, where a complex target (e.g., electrical current) is mapped onto a familiar base (e.g., water flow), is a potent cognitive tool proven to reduce cognitive load and facilitate the construction of robust mental models in technical domains [7, 8]. Similarly, narrative pedagogy—by incorporating historical events like the "War of Currents" or the discovery of induction—provides a critical socio-technical context, transforming dry theory into memorable human endeavours [9, 10]. These stories humanize the engineering process, enhancing intrinsic student motivation [11].

However, the creation of novel, context-specific, and consistently high-quality analogies and narratives for every lecture requires substantial instructional time, a factor that often limits their widespread and effective use [12]. This logistical hurdle is precisely where modern Generative AI tools, specifically large language models (LLMs) like ChatGPT, offer a transformative solution [13]. LLMs can rapidly process information and generate a variety of customized, creative, and pedagogically aligned content on demand. By using precise prompts, instructors delegate the labor-intensive content generation, effectively leveraging AI as a sophisticated co-creator of instructional materials. This process personalizes the learning experience and frees the instructor to focus on facilitating deeper conceptual discussion and critical refinement.

The remainder of this paper details the methodology, including the structured AI prompting and content verification workflow, presents quantitative and qualitative evidence of the impact, and discusses the lessons learned regarding the judicious use of AI in foundational engineering education.

2. Implementation Methodology

The practice was applied throughout a full semester in the "22EE230: Electric Circuit Analysis" course for first-year electrical engineering students at Thiagarajar College of Engineering. The total Experimental group size was 65 students. The primary comparison group (Control) was the preceding academic year's group (N=63) who received the same instructor and syllabus but without the AI-generated and storytelling components. Identified topics where students faced difficulty (Theorems, resistance, inductance, energy storage).

- Used ChatGPT to generate simple analogies, and real-life stories in parallel. Incorporated storytelling pedagogy, including:
- The “War of Currents” (Edison vs. Tesla) to explain AC vs. DC.

- Faraday's discovery of induction, told as a journey of curiosity.
- Edison's persistence with the light bulb to emphasize resistance and current.
- Blended analogies, stories, and problem-solving in lectures.
- Encouraged students to create their own analogies and short stories.

2.1 Objectives and Focus Areas

The implementation was guided by three core objectives:

1. **Simplify Abstract Concepts:** Achieve clarity for RLC components and circuit theorems (KCL, KVL, Thevenin, Superposition).
2. **Build Lasting Foundation:** Promote long-term retention beyond examination periods.
3. **Enhance Engagement:** Foster active participation and appreciation for the subject's historical and societal context.

Topics identified as traditionally difficult—and thus targeted for Experimental—included Thevenin's Theorem, the distinction between Inductance and Capacitance behaviour, and the foundational application of KCL/KVL.

2.2 The AI-Assisted Process

The central operational shift involved integrating ChatGPT into the lecture preparation phase. This process was structured into three clear steps: Prompting, Generation, and Critical Verification.

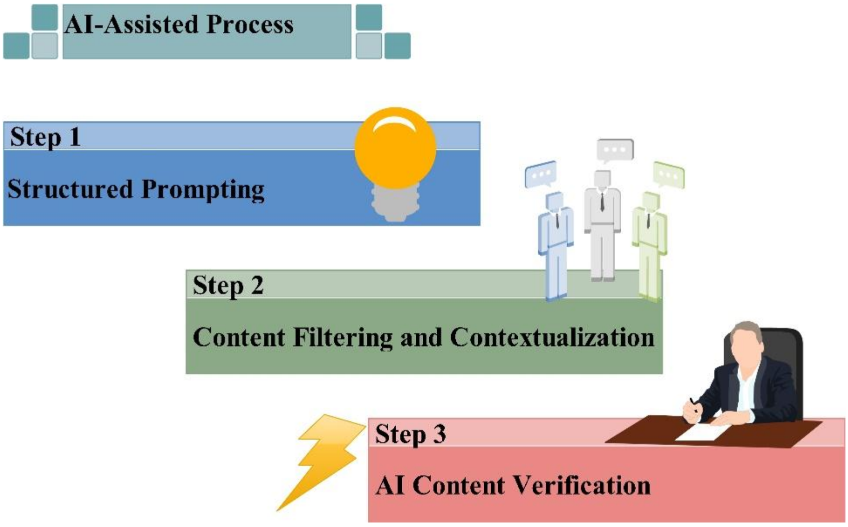

Figure 1: Steps in AI assisted Process

Step 1: Structured Prompting

Prompts were designed to be highly specific and pedagogically focused, ensuring the output was relevant and immediately usable.

Example 1: Generate an everyday-life analogy that explains the working principle of a capacitor, focusing on how it stores and releases energy. Ensure that the analogy is intuitive for first-year Electrical Engineering students

Example 2: Generate an adventure-style story that personifies an inductor as a character who resists sudden changes. The story should help students intuitively understand the inductive opposition to changing current

Sample content generated by AI in response to the prompts are as follows:

1. Kirchhoff's Current Law (KCL) – The Apartment Water Tank
Imagine an apartment with one big overhead water tank. Pipes go to each family's house.

- Some families take more water, some less.
- But the total water flowing out of the tank is exactly equal to the water flowing into the apartments.

Lesson: Just like water, electric current doesn't disappear. At a junction, the current entering = the current leaving. This is KCL.

2. Kirchhoff's Voltage Law (KVL) – The Morning Walk
A student goes for a walk around the college ground. He starts at the gate, goes around the whole ground, and returns to the same gate.

- No matter which path he takes, when he comes back, the net change in position is zero.
- Similarly, when you go around a loop in a circuit, the sum of rises and drops in voltage is zero.

Lesson: Walking around a loop in real life explains KVL in circuits.

3. Thevenin's Theorem – The Vending Machine
Suppose you go to a vending machine to buy a juice bottle.

- You don't care about the hundreds of wires, motors, and mechanisms inside the machine.
- All you see is a simple interface: you put money, press a button, and get juice.

Lesson: Thevenin's theorem does the same: it reduces a complex network into one simple voltage source and resistance. Students only need to look at the "interface" instead of the full circuit.

4. Superposition Theorem – The Two Teachers
A student is guided by two teachers at the same time.

- To really understand the help from each teacher, he imagines one teacher guiding while the other is silent, and then adds up the effects later.

Lesson: That's how Superposition works. Switch off one source at a time, calculate, then add the effects.

5. The War of Currents – Edison vs Tesla
In the late 19th century, Thomas Edison promoted Direct Current (DC) for powering homes and industries. Meanwhile, Nikola Tesla, supported by George Westinghouse, believed Alternating Current (AC) was the future, as it could be transmitted over long distances with less loss. Edison started public demonstrations to show AC was "dangerous," even electrocuting animals to prove his point. But Tesla's AC system triumphed when it successfully powered the 1893 Chicago World's Fair and later the Niagara Falls power plant.

Edison and the Bulb – The Story of Resistance
When Edison was working on the electric light bulb, he tested over 6,000 different filament materials before finding the right one. Most of them either melted, broke, or glowed only briefly. Finally, he discovered that carbonized bamboo could glow for hundreds of hours without breaking. What Edison was really battling with was resistance—the property that determines how much heat and light a filament produces.

Step 2: Content Filtering and Contextualization

The instructor acted as the essential filter. Generated content was not used raw. Analogies were selected based on relevance, familiarity (to the local student context), and clarity (avoiding false analogies that break down under scrutiny). For example, while a "water flow" analogy for current is common, AI-generated variations linking resistance to friction in pipes and voltage to hydrostatic pressure were explicitly chosen for their structural coherence.

Step 3: AI Content Verification (Addressing Correction Concerns)

To address the concern of technical inaccuracies by AI, a mandatory Verification Workflow was implemented:

1. **Technical Review:** Analogies were mentally or mathematically checked against the core physical laws.
2. **Peer/Self-Test:** The analogy was briefly tested on a non-expert or a peer instructor for intuitive clarity.
3. **Cross-Validation:** Historical stories (like the War of Currents) were cross-validated against standard historical texts to ensure the core facts and narrative sequence were accurate.

It is also worth to mention that the time spent generating three unique, vetted analogies/stories per topic using AI was approximately 10 minutes. Manually generating similar quality content would typically require 30–45 minutes of dedicated creative effort, resulting in an estimated 70% time saving in content creation for these specific pedagogical enhancements.

The enhanced content was integrated into the content delivery. Hence, resources like AI tool (ChatGPT), classroom multimedia, faculty expertise, story-based lecture notes are used throughout the course.

4. Impact and Outcomes

The following outcomes are noted:

Students reported better understanding of resistance, inductance, capacitance and circuit theorems and resulted in improved conceptual clarity.

Storytelling captured attention, making abstract concepts lively and memorable and provide Higher engagement

Students connected theory with historical context and innovation, appreciating how electrical discoveries shaped technology.

Students shows active participation and began sharing their own stories and analogies in discussions.

Enhanced performance in internal assessments and improved confidence in applying circuit laws.

The effectiveness of the integrated pedagogy was assessed using both quantitative (conceptual test scores) and qualitative (perception survey, classroom observation) metrics.

3.1 Quantitative Impact Evidence

Internal assessments focused specifically on conceptual understanding (rather than complex numerical solving) were administered to both the Experimental group (N=65) and the control group (N=63). The average score in one conceptual test showed a significant improvement.

Table 1: Conceptual test mark comparison

Group	N	Average Conceptual Test Score (Max 100)	Standard Deviation (σ)
Control (Traditional)	63	64.3%	7.9%
Experimental (AI-Enhanced)	65	78.3%	6.1%

The 14% improvement in understanding abstract component dynamics demonstrates the direct impact of the tailored, memorable analogies and stories.

3.2 Qualitative Impact and Engagement Metrics

A structured perception survey (n=43 out of 65 students) and classroom observation documented significant improvements in engagement and self-reported clarity.

Table 2: Survey Results

Survey Statement	Strongly Agree / Agree (%)
Analogies helped me understand concepts (R, L, C) faster.	93.02%
Historical stories (Edison/Tesla) made the subject more interesting.	88.37%
I feel more confident applying circuit theorems	86.04%
The class environment encouraged me to ask questions and share ideas.	88.37%

A key finding was the rise in student ownership of learning. Students began sharing their own creative analogies spontaneously. This demonstrated that the pedagogical framework successfully moved beyond mere consumption of stories to active creation and synthesis of conceptual knowledge.

5. **Discussion**

]The implementation details provided make this practice highly replicable, demonstrating that while AI tools like ChatGPT can efficiently generate creative teaching content, the instructor remains essential for filtering and contextualizing the output to avoid misleading analogies. A key insight is that storytelling becomes most effective when tightly linked to syllabus concepts and adapted to student context. The strong student engagement with historical narratives such as the "War of Currents" and "Faraday's Journey" shows how humanizing scientific ideas transforms circuit analysis from a dry topic into a compelling story of innovation. Another major outcome is the 70% reduction in content preparation time, enabling educators to focus more on interaction, personalized support, and problem-solving. However, this efficiency must be balanced with accuracy, and the structured Verification Workflow ensures that AI-assisted materials remain technically correct. Cross-validating each analogy with the relevant physical laws protects the academic integrity of the course and minimizes conceptual confusion.

5. Conclusion

The integration of AI-generated analogies, real-life examples, and storytelling pedagogy proved to be an exceptionally effective method for strengthening foundational learning in Electric Circuit Analysis. The practice successfully addressed the inherent abstractness of the subject, resulting in a significant quantitative improvement (14.7% on abstract concepts) in student conceptual test scores and a marked qualitative rise in student engagement and ownership of learning. This pedagogical model demonstrates that AI's use in education may not be in direct content delivery, but in accelerating the instructor's ability to create custom, engaging, and cognitively beneficial materials. The structured workflow presented here offers a practical, replicable framework for other engineering disciplines facing similar challenges with abstract foundational concepts. By leveraging AI judiciously, educators can shift their focus from labour-intensive content creation back to the essential art of facilitation, contextualization, and human-centered teaching.

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