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RAIL: A Reasoning-Aware AI Learning Framework to Preserve Critical Thinking in AI-Assisted Engineering Education

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ABSTRACT

The integration of Artificial Intelligence (AI) into engineering education has significantly altered students' processes for accessing information, finding solutions and grasping intricate ideas. Even though educational AI-powered tools present substantial benefits regarding accessibility, efficiency and individualized aid, over-reliance upon immediate-answer systems has the potential to compromise learners' critical thinking, logical reasoning and independent problem-solving ability. This problem has grown and highlighted the importance of designing educational AI systems that support learning without fostering cognitive dependence.

In this work, the role of reasoning-aware AI systems is examined in seeking a healthy balance between leveraging technology support and promoting cognitive growth for undergraduate engineering students. Through a review of available research on the implications of cognitive offloading, active learning, reflective practice, adaptive learning, and explainable AI, key elements influencing students' learning strategies are highlighted. Results illustrate how guided reasoning, reflective practice-based learning, adaptive learning, and clear interactions with AI can bolster knowledge retention, improve engagement and boost students' independent problem-solving skill while avoiding reliance on direct solutions from an automated source.

To this end, this study proposes the RAIL (Reasoning-Aware Intelligent Learning) Framework, an AI-supported educational design model that promotes critical thinking in AI-augmented learning situations. It comprises five interdependent components: Problem Interpretation, Guided Reasoning, Reflection Validation, Adaptive Intelligence, and Transparency and Trust. Instead of merely supplying answers, RAIL encourages active engagement by providing cues, guiding the reasoning process, facilitating reflection, and offering tailored instruction. By incorporating learning-focused processes into AI-aided instruction, the model attempts to nurture independence, improve learning longevity, and encourage responsible AI use in engineering education. The model is designed to provide insight toward developing sustainable AI learning systems that enhance human intellect rather than replacing it.

Introduction

Artificial Intelligence has integrated itself into problem solving in every field, developing tools for explanation, coding, summarizing, and teaching. In each area, willing and understanding students have used the technology to develop solutions in ways that promote their understanding. Students committing to understanding their problem through the use of the technology are more likely to retain learning and experience a low risk of cognitive dependency \cite{unesco2023}. The negative effects of cognitive dependency in the field of engineering education are even more apparent, as engineering education relies on reasoning, logical step problem solving, and adequate understanding of the problem \cite{luckin2018}. Many current AI systems are designed for efficiency first and most. If students are provided with the answer to a problem, the answer is viewed as the end of an active learning engagement and the risk of Amygdala regression in the field of engineering is apparent \cite{holmes2019}.

Active participation, reflective learning, and guided reasoning are important for better knowledge retention and enhanced problem-solving capabilities (oecd2021). Hence, it becomes imperative to build AI systems aimed at learning with the ability to preserve critical thinking and intellectual independence. This research examines how reasoning-aware AI systems can deal with

various educational needs without compromising long-term cognitive development.

Abstract

The integration of Artificial Intelligence (AI) into engineering education has significantly altered students' processes for accessing information, finding solutions and grasping intricate ideas. Even though educational AI-powered tools present substantial benefits regarding accessibility, efficiency and individualized aid, over-reliance upon immediate-answer systems has the potential to compromise learners' critical thinking, logical reasoning and independent problem-solving ability. This problem has grown and highlighted the importance of designing educational AI systems that support learning without fostering cognitive dependence.

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Background

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are more likely to retain learning and experience a low risk of cognitive dependency \cite{unesco2023}. The negative effects of cognitive dependency in the field of engineering education are even more apparent, as engineering education relies on reasoning, logical step problem solving, and adequate understanding of the problem \cite{luckin2018}. Many current AI systems are designed for efficiency first and most. If students are provided with the answer to a problem, the answer is viewed as the end of an active learning engagement and the risk of Amygdala regression in the field of engineering is apparent \cite{holmes2019}.

Active participation, reflective learning, and guided reasoning are important for better knowledge retention and enhanced problem-solving capabilities (oecd2021). Hence, it becomes imperative to build AI systems aimed at learning with the ability to preserve critical thinking and intellectual independence. This research examines how reasoning-aware AI systems can deal with various educational needs without compromising long-term cognitive development.

Key Findings

Finding 1: Reliance on AI Causes Cognitive Offload

Considering cognitive offloading, over-reliance on solutions generated by AI systems re-

duces mental processing and dealing effort among students. Research in educational

psychology shows that passive consumption of AI systems' instantaneous answers re-

duces independent reasoning development and learning retention over time (apa2023). It

is observed that students using AI systems to accomplish tasks quickly develop a poor

relationship with independent problem-solving.

Finding 2: Engaging in the Reasoning Retains Information

Research in the field of active learning highlights that students retain information effi-

ciently when they are engaged in the reasoning process (holmes2019). Providing answers

after a process of step-by-step guidance along with some of the conceptual cues and reflec-

tive questions fosters a deeper understanding unlike the delivery of answers, and advances

the understanding of the concepts and the reasoning ability of the learners.

Finding 3: Critical Thinking and Reflection-Based Learning

It is noted in the studies pertaining to the reflection learning that the students, when en-

couraged to explain their reasoning before the answers are provided to them, have highly

developed metacognitive reasoning along with the improvement in the problem-solving

skills (luckin2018). The reflection based learning encourages the students to reason about

their mistakes, critically assess their assumptions, and understand the concepts better.

Finding 4: Engagement Increases with Adaptive Learning Systems

Adaptive learning systems that personalize support based on a student's individual learn-

ing patterns and academic progress have reported higher levels of engagement and aca-

demic success [4]. The system's gradual alterations of the learning material's complexity,

the depth of explanations, and the amount of guidance provided contributes to a healthier

learning experience and significantly reduces the creation of dependency.

Finding 5: Trust is Gained from AI System Transparency

Users tend to trust AI systems more and regard them more positively when they can see the reasoning, confidence levels, and indication of sources [1]. When educational AI systems provide transparent reasoning and are used to evaluate and improve the AI's generated answers, responsibility and accountability are improved.

Proposed Idea – The RAIL Framework

This research proposes the RAIL (Reasoning-Aware Intelligent Learning) Frame-work, a conceptual AI-based educational model, to address the concerns brought to light in this research while safeguarding critical thinking and independent problem-solving skills from the potential overshadowing of AI.

Unlike legacy AI systems that prioritize the instantaneous production of answers, the RAIL framework emphasizes guided reasoning, reflective learning, personalized assis-tance, and transparency.

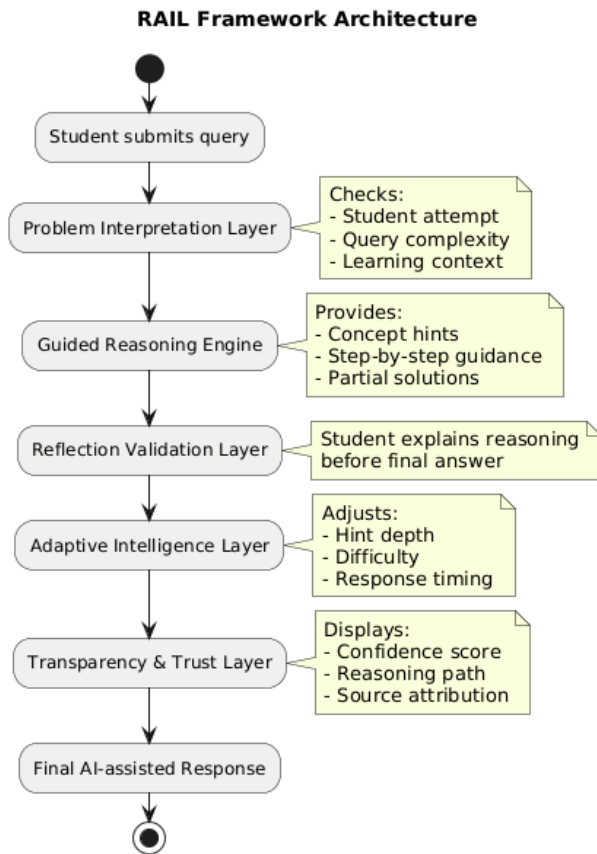


Figure 1: RAIL Framework Architecture

The framework includes five layers:

1. Problem Interpretation Layer

The system first checks if the student has tried to solve the problem on their own. Rather than offering the answer, the system focuses on helping the student to answer the question **and explain the problem. This helps break impulsive behavior to rely on the system for answers.**

2. Guided Reasoning Engine

When the solution is out of reach for the student, the system offers the next best thing - guidance. The system offers clues and hints which get progressively closer to giving away the answer. The system combines guidance to answer the question with a support system for the student.

3. Reflection Validation Layer

The system focuses on helping the student to answer the question and explain the reasoning. The system then evaluates the response if it satisfies reasoning to help the student reflect.

4. Adaptive Intelligence Layer

The system looks at the student's engagement and learning progress and assesses behavior

to customize the way the system offers help in line with the system's guidance.

5. Transparency and Trust Layer

To get students to critically assess AI-generated outputs, the system focuses on displaying confidence, reasoning and sources to improve AI's usage.

Comparative Analysis

Traditional AI Systems RAIL Framework

Instant answer generation Guided reasoning support

Passive information consumption Active cognitive engagement

Uniform assistance for all users Adaptive personalized learning

Limited transparency Explainable outputs and reasoning paths

High dependency risk Critical-thinking preservation

Expected Educational Outcomes

The proposed RAIL framework is expected to:

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- Enhance long-term knowledge retention
- Enhance ability to solve problems independently
- Lessen reliance on AI and Foster the desire to learn
- Enhance the level of trust to Educational AI

The framework could be used to balance and provide cognitive support in learning

by integrating AI-based educational tools like tutoring systems, coding assistants, and

adaptable learning platforms.

Conclusion

The positive and the negative of the integration of Artificial Intelligence in learning appear

to be of great assistance and great hindrance to learning, as in the case with supporting

learning systems. Reducing the cost in time and effort for learning by supporting students

to think and learn on their own could be the challenge. The RAIL framework describes

the design and development of reasoning-aware educational Artificial Intelligence with

cognitive engagement and reasoning to support learning processes that rely on the passive

consumption of answers to learning activities. The RAIL framework strives to support

cognitive and learning sustainability.

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