


Chapter 4

The Feedback Loop Architect: A Human-Centered GenAI Platform for Refining Personalized Feedback Ecologies in Science Education

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ABSTRACT

Effective feedback is crucial for deep learning, yet providing timely, personalized guidance remains a challenge in education, especially in science. This paper introduces the “Feedback Loop Architect,” a human-centered GenAI platform designed to create personalized feedback ecologies. The platform addresses the need for iterative feedback by simulating and supporting student-platform interactions. A key contribution is our novel methodology for creating a realistic synthetic dataset capturing the dynamics of feedback dialogues. This dataset, informed by established practices like “Sticky Note Feedback,” serves as a testbed for the platform. We demonstrate how the platform simulates learning progressions, visualizes feedback impact, and provides personalized guidance. Results from a simulation of 450 interactions across 50 students show significant improvements in scores (mean increase: 2.69 points) and answer elaboration. This work provides a framework for researchers developing educational AI, offers insights for managers, and explores ethical considerations in such systems.

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1 INTRODUCTION

1.1 The Imperative for Enhanced Feedback in Science Education

High-quality feedback is recognized as one of the most powerful educational interventions, particularly in complex domains like science education where it is crucial for conceptual restructuring (Hattie & Timperley, 2007). Despite its recognized efficacy, a significant gap persists between feedback's importance and its practical implementation. Resource constraints in typical classrooms often lead to feedback that is generic, delayed, or purely summative, failing to adequately support individual learning journeys (Jamali, 2025; Shute, 2008). Inconsistently implemented feedback can even decrease student performance (Kluger & DeNisi).

This challenge is compounded in science by its hierarchical knowledge structure and the prevalence of persistent misconceptions. Traditional approaches focusing on correctness over process often reinforce a fixed mindset, underscoring the need for a qualitative shift in feedback's nature (Baesmat & Latifi, 2023). The imperative is for a continuous, iterative learning process that cultivates growth mindsets and essential STEM skills. The current educational landscape, therefore, calls for tools that can elevate feedback from a passive receipt of information into an active process of refinement (Baesmat et al., 2021; Farrokhi et al., 2024). This goal is supported by educational neuroscience, which reveals that personalized, process-oriented feedback is neurologically optimal for learning, justifying a technological solution designed to fundamentally transform, not merely automate, feedback practices.

1.2 Defining the “Feedback Loop Architect”: A GenAI-Powered Solution

In response to this challenge, we introduce the “Feedback Loop Architect,” a Generative AI (GenAI) powered platform meticulously designed to address the complexities of providing personalized and iterative feedback in science education. At its core, the platform leverages advanced AI models to simulate student interactions with science assessment tasks, generate contextually relevant and pedagogically sound feedback, and track student progress through multiple iterations of learning and revision (Jamali, Debolt, et al., 2025). The rapid evolution of GenAI technologies, particularly Large Language Models (LLMs), has created unprecedented opportunities for educational applications. Unlike previous generations of educational technology that often relied on pre-programmed responses or simple pattern matching, modern GenAI systems demonstrate sophisticated capabilities in natural language understanding, contextual reasoning, and adaptive response generation.

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