Enhanced Question-Answering for Skill-Based Learning using Knowledge-based AI and Generative AI

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Introduction & Motivation

- Online learners often struggle to understand the "how" and "why" behind procedural skills.
- Traditional chat-based agents offer shallow explanations that hinder skill-based learning
- **Proposal**: A hybrid system combining **knowledge-based AI** and **generative AI** to generate explanations that embody teleological, causal and compositional principles.

Research Questions

RQ1: How can an intelligent agent (IA) explain how a skill functions?

RQ2: How can an IA inspect the design of a skill?

Model skills using the TMK framework[1]

- An IA can effectively explain how a skill functions if it is decomposed using the TMK (Task-Method-Knowledge) framework.
- We modeled six skills taught in a graduate-level AI course[2] using the following procedures:
  - **Task definition:** Identify the goal of a skill.
  - **Method specification:** Outline the sequence of states and state transitions to accomplish the task.
  - **Knowledge representation:** Define objects, concepts, and their relationships within the environment.

Algorithm for Skill Learning Q&A

- **Step 1:** Learner submits question.
- **Step 2:** Coach moderates and determines if it cannot answer or routes question to Knowledge Retrieval module.
- **Step 3:** Assess question complexity to determine the depth of response and fetches relevant TMK components.
- **Step 4:** Response generation iteratively refines answers.
- **Step 5:** Optimize the response to be clear and concise and send it as output to the learner.

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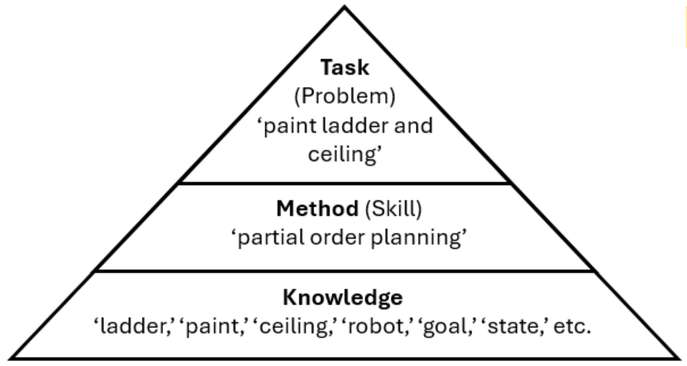

Figure 1: High-level TMK model of the 'Partial Order Planning' skill, showing hierarchical problem decomposition.

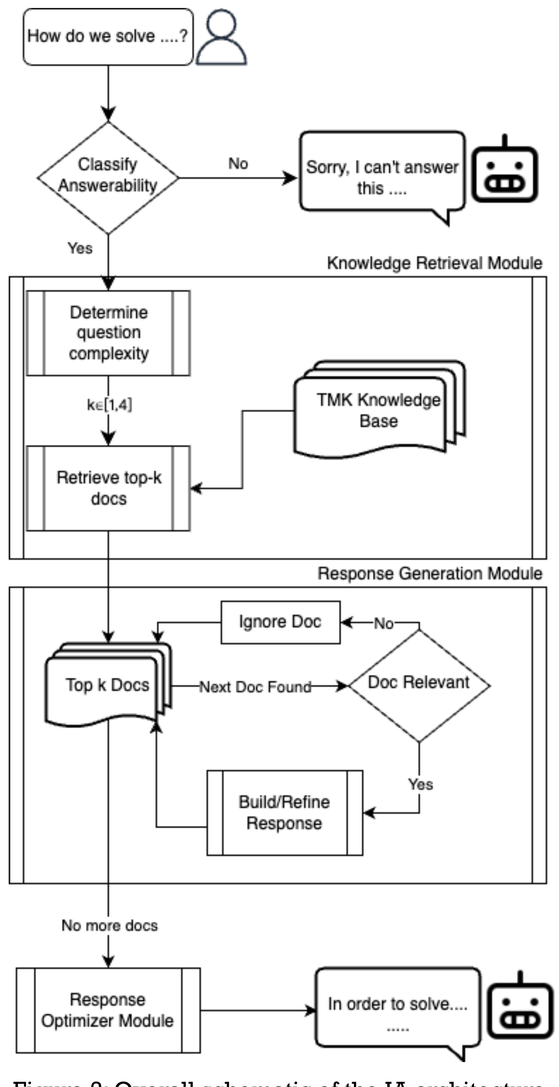

Figure 2: Overall schematic of the IA architecture.

Example Use Case

- **Skill:** Partial Order Planning (POP)
- **Learner Question:** *"What is the goal of the painting task in POP?"*
- **IA Response:** "The goal is to achieve the end state where both the ladder and ceiling are painted, ensuring actions are sequenced to avoid conflicts (e.g., paint ceiling before ladder)."
- *Compared to baseline methods, IA provides structured logic and teleological reasoning.*

Evaluation and Results

- **Developer Perception Evaluation:**
  - IA preferred in 82.14% of responses over RAG benchmark (53.57%)
- **Semantic Similarity (SBERT Scores):**
  - IA: 0.82 (Avg.) vs. Expected Responses.
- **Automated Knowledge Trace Analysis:**
  - Correct TMK file usage in 90% of queries.
  - 83% of content sourced from relevant documents.

Key Takeaways

- The IA, powered by TMK models and Generative AI, provides **deeper and more structured explanations** than traditional methods.
- Learners benefit from **teleological, causal, and compositional reasoning** in explanations.
- Enhanced understanding of **procedural knowledge** leads to improved **skill-based learning** outcomes.

Future Work

- **Automating** TMK model creation to reduce development time.
- Expanding to **episodic knowledge** queries.
- Conducting **real-world learner studies** to validate practical impact.

References

1. Murdock, J. W., & Goel, A. K. (2008). Meta-case-based reasoning: self-improvement through self-understanding. *Journal of Experimental & Theoretical Artificial Intelligence*, *20*(1), 1-36.
2. Knowledge-based AI course, Georgia Tech, OMSCS program.