# Code Soliloquies for Accurate Calculations in LLM based Intelligent Math Tutors
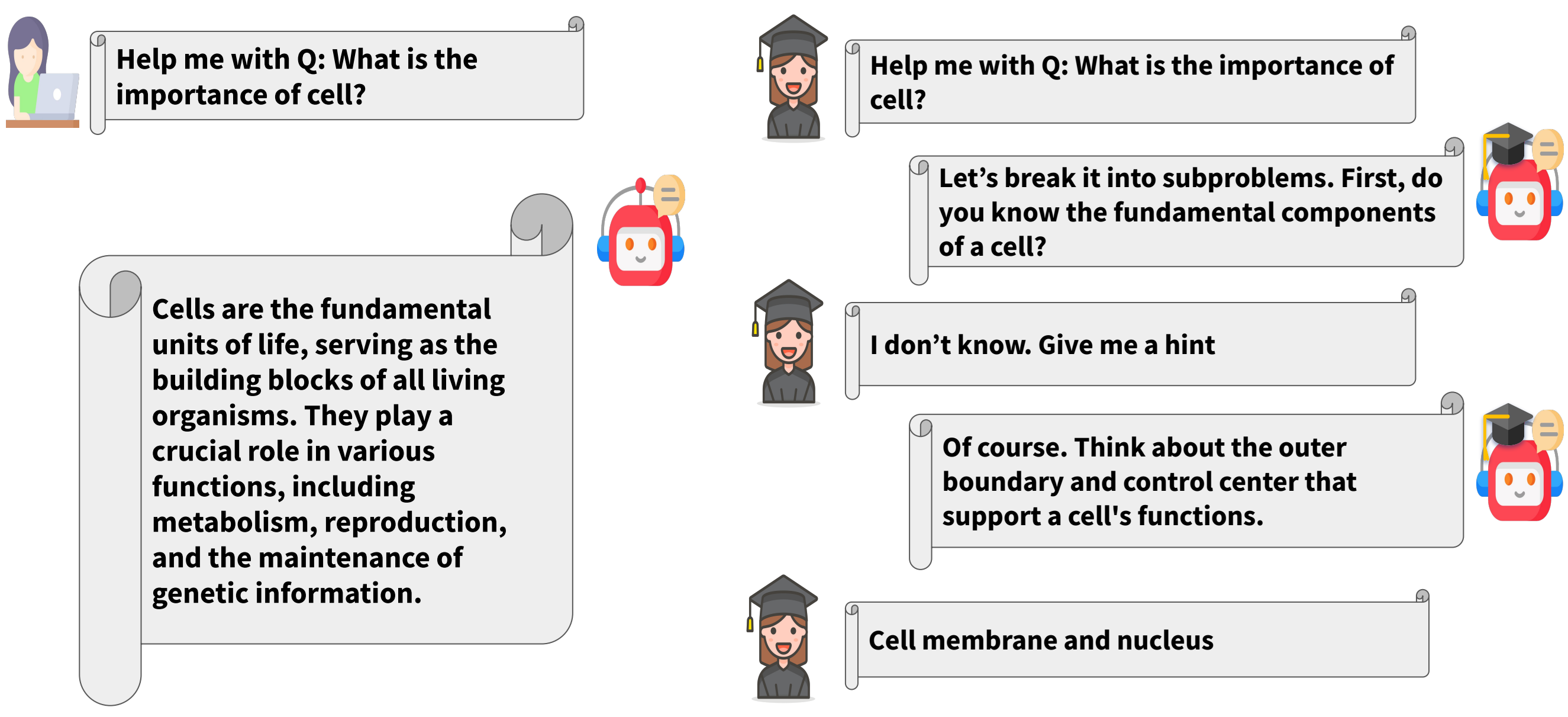
Shashank Sonkar[1], Xinghe Chen[1,2], MyCo Le[1,2],
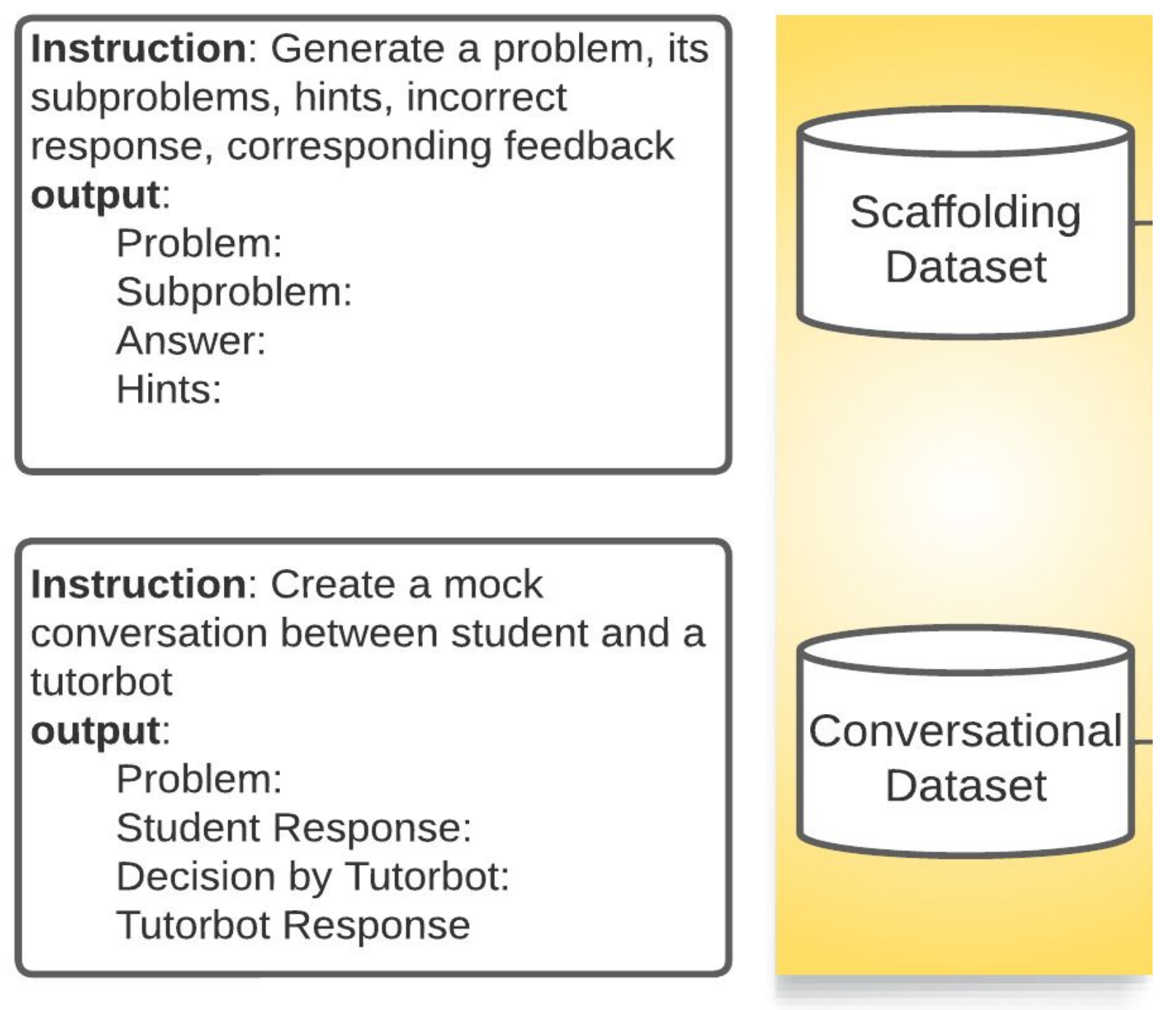Naiming Liu[1], Debshila B. Mallick[2], Richard G. Baraniuk[1,2]

1. Rice University, 2. OpenStax

## LLMs aligned to be "Helpful" and Honest

**Helpful to whom?** Demands of a typical user (left) vs a student (right) differ!
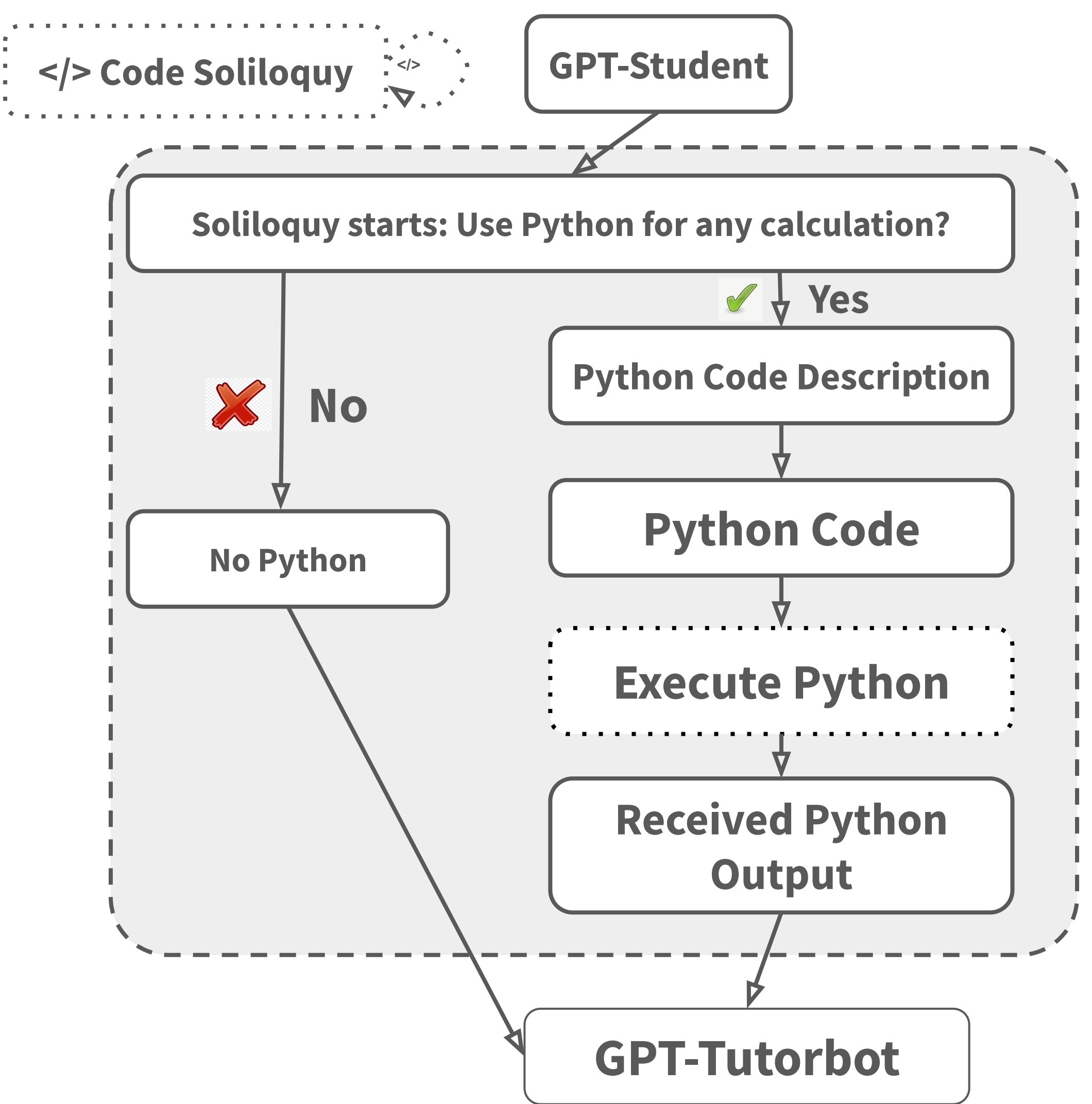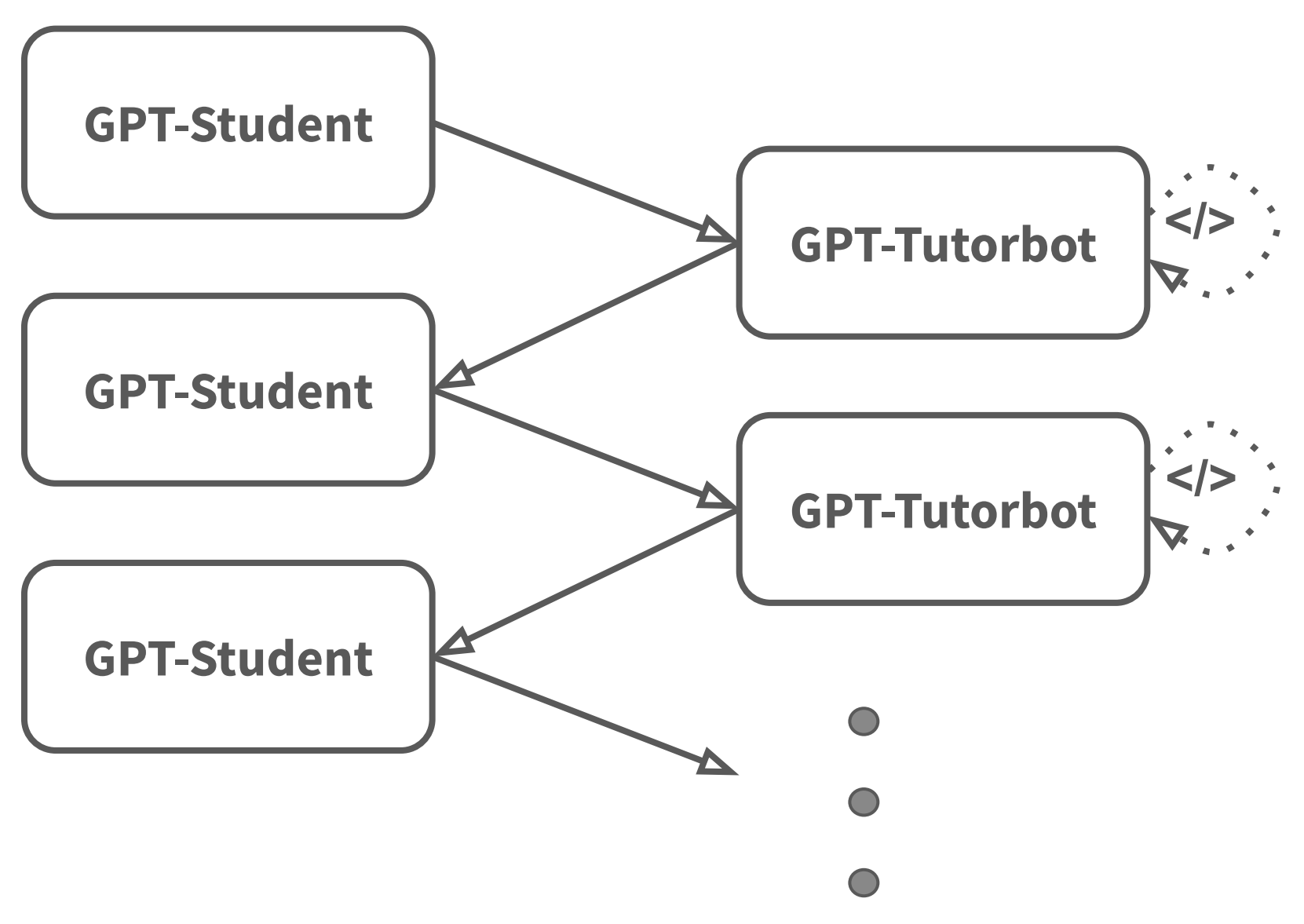**Necessary to develop critical thinking and promote learning in students**

**Help me with Q: What is the importance of cell?**

**Cells are the fundamental units of life, serving as the building blocks of all living organisms. They play a crucial role in various functions, including metabolism, reproduction, and the maintenance of genetic information.**

**Help me with Q: What is the importance of cell?**

**Let's break it into subproblems. First, do you know the fundamental components of a cell?**

**I don't know. Give me a hint**

**Of course. Think about the outer boundary and control center that support a cell's functions.**

**Cell membrane and nucleus**

## CLASS Framework

**Instruction**: Generate a problem, its subproblems, hints, incorrect response, corresponding feedback
**output**:
 Problem:
 Subproblem:
 Answer:
 Hints:

**Instruction**: Create a mock conversation between student and a tutorbot
**output**:
 Problem:
 Student Response:
 Decision by Tutorbot:
 Tutorbot Response

Scaffolding Dataset
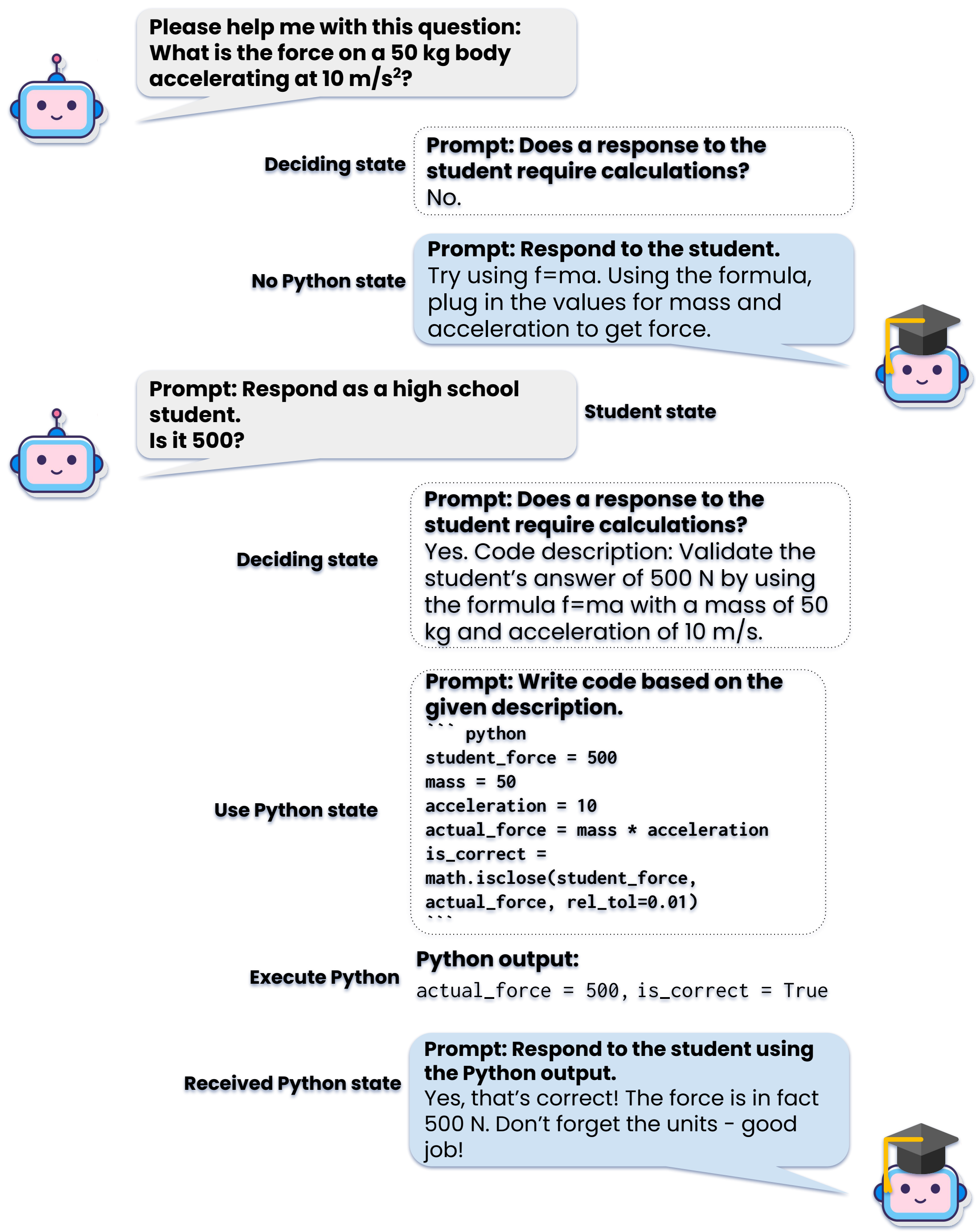
Conversational Dataset

## Two changes to CLASS Framework

1. GPT-Tutorbot talks to GPT-student to generate mock conversation
2. GPT-Tutorbot engages in a code soliloquy if its reply to student warrants any math calculation or student's calculation verification

GPT-Student

GPT-Tutorbot </>

GPT-Student

GPT-Tutorbot </>

GPT-Student

</> Code Soliloquy </>

GPT-Student

**Soliloquy starts: Use Python for any calculation?**

✔ **Yes**

✘ **No**

**Python Code Description**

**No Python**

**Python Code**

**Execute Python**

**Received Python Output**

**GPT-Tutorbot**

## Mock Conversation with Code Soliloquy

**Please help me with this question: What is the force on a 50 kg body accelerating at 10 m/s²?**

**Deciding state** — **Prompt: Does a response to the student require calculations?** No.

**No Python state** — **Prompt: Respond to the student.** Try using f=ma. Using the formula, plug in the values for mass and acceleration to get force.

**Student state** — **Prompt: Respond as a high school student.** Is it 500?

**Deciding state** — **Prompt: Does a response to the student require calculations?** Yes. Code description: Validate the student's answer of 500 N by using the formula f=ma with a mass of 50 kg and acceleration of 10 m/s.

**Use Python state** — **Prompt: Write code based on the given description.**
```python
student_force = 500
mass = 50
acceleration = 10
actual_force = mass * acceleration
is_correct =
math.isclose(student_force,
actual_force, rel_tol=0.01)
```

**Execute Python** — **Python output:** `actual_force = 500, is_correct = True`

**Received Python state** — **Prompt: Respond to the student using the Python output.** Yes, that's correct! The force is in fact 500 N. Don't forget the units - good job!

## Evaluation Metrics (SME)

| Python Usage Accuracy | Python Non-Usage Accuracy | Code Compilation | Calculation Verification |
|:---:|:---:|:---:|:---:|
| 1.0 | 1.0 | 0.97 | 0.88 |