FABLE: A Critical Thinking Tutor

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Abstract. This report documents the development of ***F**allacy **A**wareness and **B**ias **L**earning **E**nvironment* (FABLE), an interactive tutoring system designed to build critical thinking skills. While existing approaches for critical thinking instruction are disengaging, inflexible, and passive, FABLE provides an interactive and engaging environment for learning. Using AI techniques to model learner progress and guide the learning process, FABLE encourages understanding while engaging learners in a space-themed story. As users progress through short readings and quiz questions, they develop critical thinking skills in a way that feels like a game.

Problem Statement

In an increasingly complex world where information is readily available, people often struggle to discern credible arguments from flawed reasoning, leading to the prevalence of logical fallacies and cognitive biases in everyday decision-making. Even in educational settings, students often lack the critical thinking skills necessary to identify and analyze fallacies and biases, resulting in misunderstandings and misinformed opinions. A dedicated fallacy and bias tutor is essential to equip learners with the tools to recognize common logical errors, understand the psychological underpinnings of biases, and develop robust analytical skills.

Existing methods for teaching logical fallacies and cognitive biases predominantly rely on traditional textbooks and quizzes, which often fail to engage students effectively. While informative, these approaches can be dense and dry, presenting information in a way that lacks interactivity and real-world application. This can lead to a passive learning experience, where students memorize definitions and examples without truly understanding the concepts or their relevance. As a result, students may find these methods tedious and uninspiring, leading to disengagement and a lack of motivation to delve deeper into the subject matter. To foster a more dynamic and engaging learning environment, it is essential to explore innovative teaching strategies that encourage active participation, critical analysis, and practical application of fallacies and biases in everyday situations.

This project addresses the following main challenges:

Disengagement. Traditional methods fail to engage students, leading to boredom.
Passive Learning. Students may resort to rote memorization rather than internalizing concepts.
Inflexibility. Students need an individualized experience to learn effectively.

By addressing these issues, an ITS can foster a more informed and discerning populace, capable of engaging in constructive discourse and making sound judgments in both academic and real-world contexts.

Background

The study of logical fallacies and cognitive biases is crucial for fostering critical thinking and informed decision-making in an era characterized by information overload and pervasive misinfor-

mation. Logical fallacies are errors in reasoning that undermine the logic of an argument, while cognitive biases are systematic patterns of deviation from norm or rationality in judgment [1]. Both concepts are essential for understanding how individuals process information and make decisions [2]. Unfortunately, most educators neglect critical thinking skills, resorting instead to the belief that students develop critical thinking skills as they learn other topics [3].

Traditional educational methods for teaching these concepts have primarily relied on textbooks and quizzes. While textbooks serve as valuable resources for foundational knowledge, they often present information in a linear and static format that can be disengaging for students [4]. Research indicates that passive learning environments, such as those dominated by lecture-based instruction, can lead to lower retention rates and diminished critical thinking skills [5]. Quizzes, while useful for assessment when interspersed during instruction, frequently emphasize rote memorization over the application of knowledge, which can hinder students' ability to engage with the material meaningfully [6,7].

Moreover, the lack of interactive and practical applications in traditional methods can result in students struggling to connect theoretical concepts to real-world scenarios. This disconnect is particularly concerning given that cognitive biases and logical fallacies are prevalent in everyday decision-making, from personal choices to public discourse [8,9]. As such, there is a pressing need for innovative teaching strategies that promote active learning, critical analysis, and the practical application of these concepts.

Recent studies have highlighted the effectiveness of alternative pedagogical approaches, such as collaborative learning, gamification, and experiential learning, in enhancing student engagement and understanding [10, 11]. These methods encourage students to actively participate in their learning process, fostering a deeper comprehension of logical fallacies and cognitive biases. By integrating these innovative strategies into the curriculum, educators can better equip students with the critical thinking skills necessary to navigate an increasingly complex information landscape.

Approach

To make progress toward resolving the main challenges, this report presents ***F**allacy **A**wareness and **B**ias **L**earning **E**nvironment* (FABLE). This section describes the development approach from a software perspective, and the approach for each of the main challenges, describing the development of major design elements for FABLE.

Disengagement

To tackle the problem of student disengagement, FABLE has been designed to immediately engage students. FABLE takes a twofold approach to this problem, as critical thinking skills have a high potential to disengage students.

First, FABLE was designed to be heavily themed, with game and story elements throughout. The entire ITS is set in a science fiction world: the user is responsible for learning skills of logical communication to act as a space diplomat and save the galaxy. The visual design of FABLE closely resembles the style of retro "space-age" video games, and the excessive theming is intended to provide small distractions from the learning process. This provides students with the opportunity to not only apply critical thinking skills to real-life-adjacent problems, but it imposes a higher degree of social pressure to boost engagement.

Second, students are never expected to work on a single task for more than one minute, on average. Lesson text is interspersed with quiz questions to test understanding, so students are required to actively participate in the learning process.

Passive Learning

FABLE is designed to require a high degree of student interaction. After short textual explanations of topics, students answer multiple-choice, multi-select, and free-response quiz questions. These questions are themed to reflect the narrative throughout FABLE. For example, an explanation of propositional logic reads as follows:

> The president of Planet Zog has to keep her population safe and happy. She has a lot of decisions to make, and she needs to use logical operations to help her. For example, if the weather is nice AND the streets are clean, people can go to work. If the weather is NOT nice OR the streets are covered in slime, everyone should stay home.

This is followed by an intuitive explanation of the AND, OR, and NOT operations. The following quiz question evaluates student understanding after this explanation:

> The president's assistant needs to write a program that checks if the weather is nice and the streets are clean. If both conditions are true, the program should allow people to go to work. If the streets are clean AND the weather is NOT nice, what should the program do?
> A) Allow people to go to work.
> B) Require people to stay at home.

Students are allowed to request hints, and scaffolding helps learners progress without feeling frustrated. During evaluation, a request for a hint is considered an incorrect answer, as it shows the student was unable to complete a question. The following hint may be presented to a user who fails to answer this question correctly:

> Both conditions must be true for the result to be true. That means that if the streets are NOT clean, OR if the weather is NOT nice, people should stay home.

During development, experiments were conducted with an advancement timer to prevent students from advancing without engaging with course content. Essentially, each page would require 3 to 10 seconds to pass before a student could move on or answer a quiz question. In tests, however, students reported that their objective became beating the timer rather than focusing on the content. Because it did not benefit students, the timer has been removed in the final version of FABLE.

Inflexibility

The core benefit of interactive learning as opposed to user-guided reading and quizzes is individualized learning. FABLE allows students to learn and practice at their own pace by estimating the probability that a certain topic has been mastered.

First, FABLE assumes a student has no advance knowledge of a topic. For students with existing understanding, FABLE avoids student frustration by allowing knowledgable students to quickly pass

through exercises. Students who are struggling, however, are offered hints and opportunities to retry tasks.

Further, FABLE is completely self-paced, and it saves user progress regularly. It is possible to complete the entire course in an afternoon, but it also allows completion of one unit at a time over the course of several months. Because its target audience includes both children in school and adults with busy lives, FABLE is designed to provide as much time-based flexibility as possible.

Development and Evaluation

This section describes design decisions and their evaluation.

Software Development

FABLE is developed in the Rust language. While Rust is not a traditional choice for building tutoring systems, it was selected due to the following advantages:

- It is highly cross-platform-compatible, allowing FABLE to run on many machines without extensive adaptation;
- The developer is actively improving skills in Rust, and this project was an appealing opportunity for skill building; and
- It includes all the necessary components to enable the development of this project.

The software is divided into the following primary components:

Data. The course information is stored in JSON files that detail each learning module. Each module contains many screens (i.e., text or quiz questions).

Course. The `course` includes a progress tracker for each module, as well as the implementation of the main loops of the ITS. It progresses through story elements and interacts with data. It includes a simple Bayesian Knowledge Tracing approach to model learners' progress.

Learner. The `learner` contains the learner model, storing a separate profile for every user. The learner model can be loaded from and saved to a file, allowing students to stop and resume learning at any time.

Thematic Elements

The design of FABLE is intended to be reminiscent of retro, space-age video games. The user is initially greeted by a welcome message, shown in Figure 1. From the first moment, this theming immerses a user, engaging them completely in the learning experience.

Students are periodically reminded of the fact they are learning critical thinking skills (i.e., students learn the names of fallacies and biases). This is most clear in the progress report, which is shown to the user at a high frequency to encourage learning and show a visual indicator of progress. Figure 2 shows an example progress report for a student who has attempted—but not mastered—most lessons.

Quiz questions and their hinting system follow predictable formats, allowing users to begin learning without requiring training for the interface. Figure 3 shows an example fill-in-the-blank quiz question and the resulting hint upon an incorrect response.

Fig 1. Welcome messages in the FABLE interface

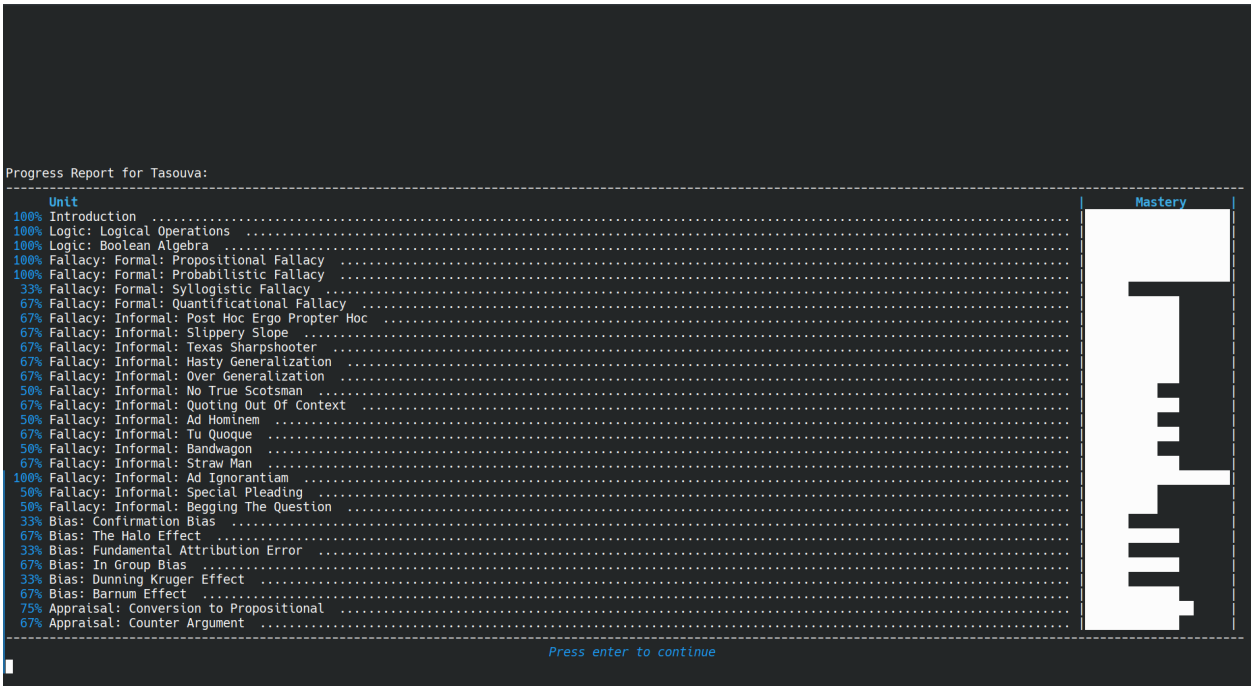

Fig 2. Progress report in the FABLE interface

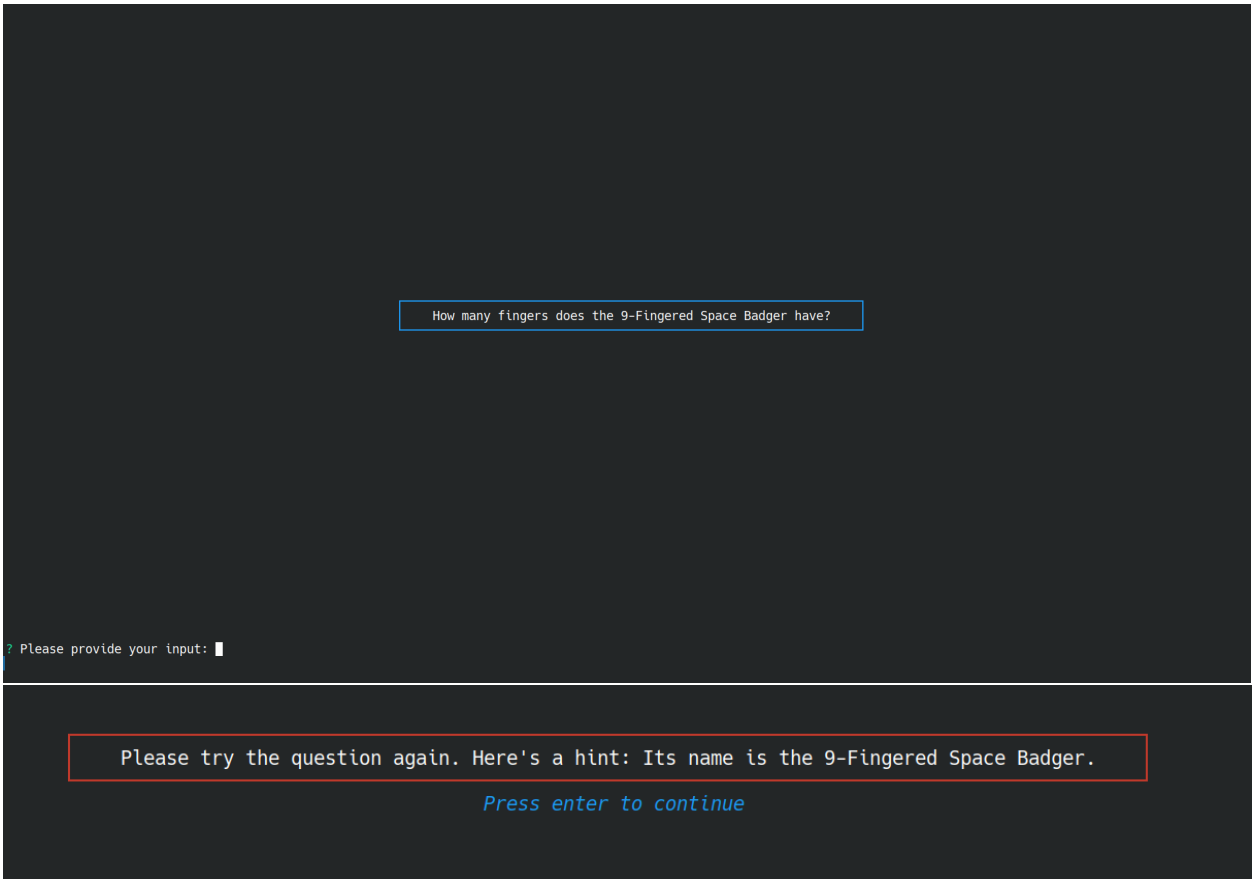

Fig 3. Quiz question and hint in the FABLE interface

Testing & Evaluation

While a more comprehensive user study would be preferred, FABLE has been tested extensively by its developer and was presented to a single user for evaluation. This user found the experience to be intuitive, reporting that it was a preferable alternative to a traditional textbook. FABLE and its source code are available as public open-source software[1], and users are encouraged to test the tool and provide feedback.

Next Steps

In the future, it is desirable to integrate a satisfiability solver (such as Z3 or Yices) to aid in the generation of logically sound or fallacious clauses in propositional logic. Further development can include integrating GPT into the story component. This hybrid approach could enable the automated generation of logically sound text accompanied by a user-customizable story. Further, developments to the interface are always desirable.

AI Use Statement

AI tools were used in the development of this project in the following ways:

- ResearchRabbit[2] was used to explore related work and citations.
- GPT 4o-Mini was used to generate story elements of FABLE, which were manually validated and edited.
- Github Copilor was used to quickly complete otherwise monotonous code generation tasks, but the bulk of code writing was performed by hand.

[1] Repository available at `https://gitmoss.fyi/mossbiscuits/fable`

[2] `https://www.researchrabbit.ai`

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