Designing Effective Software Tools for Enhancing K-12 AI Education

Pragathi Durga Rajarajan, Dr. Fred Martin

pragathidurga.rajarajan@my.utsa.edu
(210) 779 5858

Abstract

To prepare children for a future immersed in artificial intelligence (AI) technology and ensure they become responsible users of these applications, it is important to introduce AI concepts at a young age to develop their AI literacy and computational literacy early-on. However, effectively teaching AI concepts to young learners presents unique challenges. At the University of Texas at San Antonio (UTSA), the *Developing AI Tools for K-12* course explores effective methods for introducing AI to middle school students by developing and evaluating software tools, including FaunaForest and IntoTheRabbitHole, for teaching AI concepts. These tools were tested at a local school. Our findings highlight key design principles that enhance engagement and student learning. We found that high interactivity, game-based approaches, and structured guidance improved student engagement and understanding. Applications that provided clear instructions and step-by-step progression were enjoyed. Additionally, incorporating visuals instead of explanatory text helped to both engage children and make abstract AI concepts more intuitive. Challenge-based activities further increased student enjoyment and participation. This work underscores the potential of interactive software as a tool for introducing AI to children and provides insights into effective practices for designing educational AI applications.

Introduction

Background

- As AI technology rapidly develops, people are increasingly exposed to AI in various forms and applications [1]
  - Large language models, social media filters, etc.
- To better prepare children for a world dominated by AI technologies, it is critical to develop their AI literacy [2]
  - AI literacy: competencies to evaluate, use, and understand different AI technologies [3]
- Early-life exposure can help children better understand the inner workings and limitations of AI [4]

Objectives

- Develop software tools to introduce middle school students to various AI concepts
- Determine and evaluate the effective design principles for creating educational software tools for middle school students

Methods

- Multiple software tools were developed in a UTSA research course in the Spring and Fall semesters of 2024
- Tools were tested with middle school students
- Data Collection: pre-survey, software tool interaction data, audio/screen recordings, and post-survey
- Qualitative and quantitative data analysis and comparison to gain insight on best design aspects for enhancing K-12 AI education

Results

FaunaForest teaches decision trees with interactive decision tree puzzles and a timed challenge level.

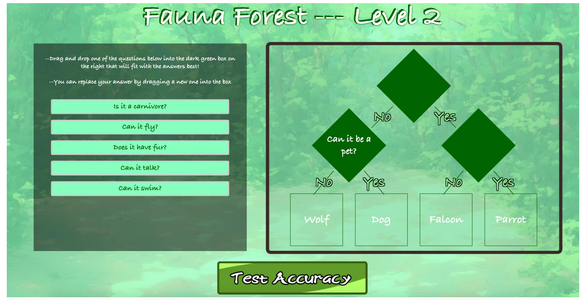

Figure 1: FaunaForest level 2 user interface

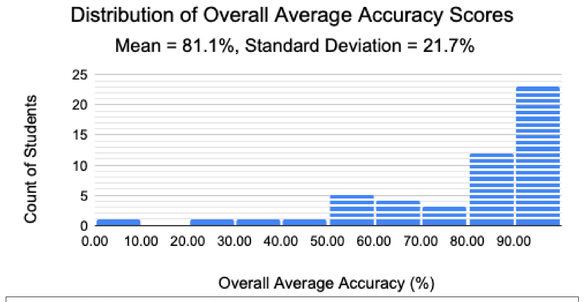

Figure 2: Distribution of the participants' overall average accuracy, which averages their accuracy across all 3 levels of FaunaForest

A two-sample t-test found a statistically significant difference in level 3 average accuracy between students who played level 3 exactly once versus more than once (p-value = 0.044).

72.3% of students answered a post-survey decision tree traversal item correctly.

IntoTheRabbitHole teaches Depth-First and Breadth-First Search (DFS and BFS) by having students use them to help a rabbit search for its carrot in training levels and a timed challenge level.

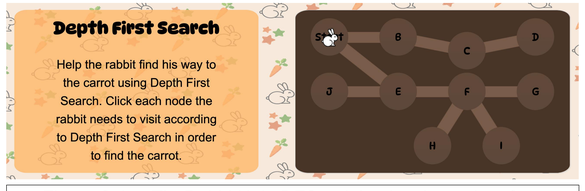

Figure 3: IntoTheRabbitHole DFS training level user interface

Results - con't

Table 1: Mean of students' average accuracy scores across all DFS and BFS puzzles they completed in IntoTheRabbitHole.

Search Algorithm	Mean (%)	Standard Deviation (%)
DFS	85.3	11.9
BFS	82.1	10.3

Table 2: Percentage of students who answered a DFS traversal item correctly on the pre-survey versus the post-survey.

% Students Correctly Answering DFS Traversal Item	
Pre-survey	**Post-survey**
28.6 %	67.3 %

A McNemar's Test yielded a p-value of 0.001315 and effect size of 4.6, indicating a statistically significant difference in the proportion of students who answered a DFS traversal item correctly on the pre-survey versus the post-survey.

53.1% of students answered a similar BFS traversal item correctly on the post-survey.

Students gave IntoTheRabbitHole a mean score of 3.85 out of 5 (standard deviation = 1.04) when asked to rate how fun the experience was.

Effective Design Principles

(1) Interactivity and (2) Visualizations

Table 3: Responses to post-survey item asking students which features of FaunaForest they found useful.

Answer	Count of Students
Interactive Activities	36
Explanatory Text	29
Visualizations	23
"My Intellect"	2
"Nothing"	1

- Observations suggested that the interactive nature of FaunaForest and IntoTheRabbitHole kept students engaged

(3) Structured Guidance

- Software tools with clear instructions and structured organization were more effective in engaging students
  - FaunaForest had 3 levels
  - IntoTheRabbitHole had 3 sets of levels:
    - DFS Training, BFS Training, and Challenge
  - Progress bar in IntoTheRabbitHole

Results - con't

(4) Game-Based and (5) Challenge Activities

- FaunaForest and IntoTheRabbitHole had game-like designs
- Students had fun with the timed challenge levels in FaunaForest and IntoTheRabbitHole
  - Many students enjoyed the game-like nature of the timed challenge levels in FaunaForest and IntoTheRabbitHole
    - Students would compete to get the highest score
  - One student particularly enjoyed FaunaForest's challenge level and chose to stay at our table for the remainder of the after-school session instead of rotating to other applications
  - One student especially loved IntoTheRabbitHole's challenge level, playing it repeatedly to beat the high score
    - He accurately explained DFS and BFS to friends and exclaimed "I loved this!"

Conclusions

- FaunaForest was successful in teaching most students about decision tree structure and functionality
- IntoTheRabbitHole effectively introduced DFS and BFS
- Software tools have great potential for supporting in-classroom K-12 AI education initiatives
- Effective design principles for creating useful AI education tools for middle school students:
  1. Interactivity
  2. Visualizations
  3. Structured Guidance
  4. Game-Based Design
  5. Challenge Activities

References

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