Designing an Adaptive Learning Algorithm for Standardized Test Preparation

GSCP: Research Proposal

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Contents

1 Abstract/Executive Summary

This research proposal aims to develop an adaptive learning algorithm for standardized test preparation, focusing on multiple-choice question-based subjects such as SAT, GRE, GMAT, including O and A level subjects. The algorithm will leverage artificial intelligence and machine learning techniques to personalize the learning experience, increase learning speed, and provide an accurate assessment of the topic proficiency of the user. Online learning platforms have revolutionized education by offering flexible and accessible learning opportunities. However, existing platforms often lack personalized learning experiences and fail to address the time-constraint issues students face in attempting questions from massive question banks. This research seeks to bridge this gap by designing an algorithm that optimizes question selection based on the user's strengths and weaknesses, and provides students with exposure to various question types. The data collection phase will involve selecting MCQ questions from the past 10 years (2012-2022) of O level Physics (5054) exams, with 50 questions per topic and a total of 24 topics. These questions will be tagged based on topic and difficulty level. Synthetic data will also be generated to simulate student responses and assess the algorithm's adaptivity. The research outcomes will provide insights into the effectiveness of the adaptive learning algorithm in terms topic proficiency, and user satisfaction (optional) The proposed research has significant implications for improving standardized test preparation and personalized education. The research outcomes and deliverables will contribute to the field of adaptive learning systems and inform the design of future educational technologies.

2 Introduction and Problem Statement

2.1 What is that you want to research?

Adaptive learning systems involve AI-powered tutoring systems that aim to personalize the learning experience for individual students. By using artificial intelligence and machine learning techniques, these systems constantly asses a student's performance and provide in real-time, individualized feedback to the student. Also, they diagnose students' strengths and weaknesses to adapt the instruction accordingly by adjusting the difficulty of the material. Furthermore, it involves using data analytics techniques to analyze a student's learning patterns, pace, and preferences to recommend learning resources such as videos and resources to improve the overall learning experience. These systems have the potential to improve learning outcomes and student engagement significantly.

To be more specific, this research is focused on Standardized tests, such as the SAT, O and A level examinations in subjects like Physics, Chemistry, Math, Economics, and the GRE, GMAT, etc. Preparing for these tests effectively and efficiently can be challenging due to the vast amount of content and the need to cover various topics and question types. The objective of this research is to design an algorithm that addresses two key goals:

1. Increased Learning Speed: The algorithm aims to optimize the learning process by efficiently allocating study time and resources. Traditional methods often involve redundant or repetitive questions that test the same concepts or offer similar difficulty levels. In contrast, the proposed algorithm will intelligently select and present a diverse range of questions, covering different concepts from within chapters and difficulty levels. This approach will expose learners to a comprehensive set of question types, enabling them to grasp the full spectrum of knowledge required for the standardized tests.

2. Topic Proficiency Assessment: The algorithm will provide learners with a clear sense of their proficiency in each topic covered by the standardized test. By analyzing the learner's performance on specific question categories or topics, the algorithm will estimate their proficiency level and identify areas that require further

attention. This assessment will enable learners to focus their efforts on strengthening their weak areas and optimizing their study plan accordingly.

By achieving these two goals, the algorithm aims to enhance the learner's overall preparedness, leading to improved test scores. The adaptive learning approach, tailored to the individual needs of the learner, will optimize their study time, reduce redundancy, and provide valuable insights into their knowledge gaps and strengths. By designing an algorithm that facilitates efficient and personalized learning, this research aims to contribute to the field of adaptive learning systems and provide learners with a more effective and streamlined approach to test preparation.

2.2 What is the background?

Online learning platforms like Alt Academy, Coursera, and Udemy hold the potential to disrupt traditional tuition systems by providing more flexible and accessible education opportunities to students. By leveraging technology, online learning platforms can offer students a more comprehensive range of courses and learning material and allow them to learn at their own pace. This can help address traditional tuition systems' constraints, such as rigid schedules and high costs. However, these learning platforms lack integration of artificial intelligence and machine learning to offer a truly personalized learning experience. This one-size-fits-all approach fails to cater to each student's unique needs and abilities.

Standardized tests, such as the SAT, O and A level subjects (Physics, Chemistry, Math, Economics), and the GRE, have seen a significant increase in the size of question banks over the years. Due to time constraints, however, students cannot attempt all available questions. Subsequently, they recognize the importance of exposure to a diverse range of question types to enhance their preparedness for these tests. Considering these factors, there is a need to develop a system that exposes the student to as many different types of questions as possible based on his strengths and weaknesses.

We believe that our experience as current students, combined with our CS skills, makes us well-positioned to contribute to developing and implementing intelligent tutorial systems. This has the potential to revolutionize education that benefits students and teachers alike.

3 Literature Review

Wang, Christensen, Cui, Tong, Yarnall, Shear, and Feng (2020) conducted research on Chinese students comparing learning by means of teachers and Squirrel AI Learning system. The study concluded that in both small and large groups of students, AI learning demonstrated significant gains over students receiving education from teachers [1].

In 2013 Walkington also conducted research on intelligent tutoring systems (ITS). His research on 145 ninth-grade students showed that students given personalized out-of-school areas conditions solved algebra problems faster and they continued to write symbolic equations for normal story problems with increasingly complex structures more accurately and with greater efficiency[2]. In another research Chrysafiadi and Virvou (2013) used Fuzzy Cognitive Maps (FCMs) for taking into account learner's knowledge level on related concepts. FCMs were used to represent knowledge dependencies graphically and show how different concepts in a subject are connected and how they influence each other [3].
Furthermore, Adaptive Mastery Testing (AMT) was developed recently for students to test themselves repeatedly until they were declared a master from a non-master in the subject. Instead of opting for a binary approach, our

research aims to rank the user in each of the topics for a better overall assessment[7]. Moreover, [6] discusses the effectiveness of different models using in the development of an Intelligent tutoring system.

4 Research Questions/Aims

The scope of this project encompasses the design and development of an algorithm for adaptive learning systems targeting standardized tests that consist of multiple-choice questions (MCQs). Specifically, the algorithm aims to enhance the learning speed and proficiency assessment of students preparing for tests.

Method:

- How can adaptive learning systems leverage AI and machine learning techniques to personalize the learning experience for individual students?
- How can the algorithm accurately assess students' topic proficiency by analyzing their performance on specific question categories or topics?
- How accurately does the algorithm assess students' topic proficiency in each subject area covered by the standardized tests?
- How can the difficulty of learning materials be dynamically adjusted to match the individual student's strengths and weaknesses?
- What data analytics techniques can be used to analyze students' learning patterns, pace, and preferences?

Testing:

- How can the algorithm effectively optimize the learning process by presenting a diverse range of questions, covering various concepts and difficulty levels, to increase the speed at which students learn?
- How can we effectively assess and validate the level of personalization achieved by the adaptive learning algorithm in catering to individual learners' needs and preferences?
- How do we measure the alignment between the algorithm's recommendations and the individual learner's needs?

Experience (Optional):

- To what extent does the adaptive learning algorithm improve students' overall test performance and scores in comparison to non-adaptive learning approaches?
- How do students perceive the adaptive learning system in terms of usability, engagement, and overall satisfaction?

5 Methodology

- **Research Design/Approach:**
  The study will involve the development and implementation of an adaptive learning algorithm for standardized test preparation, focusing only on MCQ-based subjects such as Physics, Chemistry, Math, Economics, and GRE.

- **Theoretical/Analytical Framework:**
  The theoretical framework for this research will draw upon the principles of reinforcement learning & probabilistic heuristics. The adaptive learning algorithm will incorporate machine learning techniques to dynamically adjust question selection and difficulty levels based on learners' performance.

- **Data Collection:**
  For the data collection phase of your research, the plan is to select multiple-choice questions from O-level Physics (5054) from the past ten years (2012-2022). The aim is to gather 50 questions per topic, covering a total of 24 topics. These questions will be tagged based on their topic and difficulty level.

- **Data Analysis:**
  To simulate student responses and test the adaptive learning system, synthetic data will be generated. This synthetic data will mimic different student profiles with varying strengths and weaknesses. The purpose is to assess whether the adaptive learning system effectively adapts to each student's individual abilities and provides personalized learning experiences.

6 Outcomes and Deliverables/Expected Results

The two primary outcomes of the research are as follows.

- Adaptive Learning Algorithm: The development of an effective adaptive learning algorithm tailored to standardized tests with MCQs. This algorithm will optimize the learning process by selecting diverse question types and adjusting difficulty levels. Its value lies in providing a systematic approach to test preparation that maximizes efficiency and minimizes redundancy, helping learners cover a wider range of concepts and ultimately improving their overall preparedness.

- Proficiency Assessment: The student/learner should be able to assess their performance in each topic of a subject and be provided with insights into their learning to understand where efforts are needed.

7 Implementation Plan

Week	Activities
Week 1	Literature Review
Week 2	Literature Review & Tagging questions
Week 3	Design and develop the adaptive learning algorithm prototype and student model
Week 4	Design and develop the adaptive learning algorithm prototype and student model
Week 5	Implement the algorithm
Week 6	Implement the algorithm
Week 7	Determining analytics for users
Week 8	Implementing Analytics
Week 9	Validating the algorithm (Test the algorithm for correctness i.e. evaluate it in terms of diverse question selection and difficulty adjustment.)
Week 10	Iterate and enhance the algorithm

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