Self-Evolving Adaptive Learning for Personalized Education

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Abstract. Primary and secondary education is a crucial stage to build a strong foundation before diving deep into specialised subjects in colleges and universities. To excel in the current education system, students are required to have a deep understanding of knowledge according to standardized curriculums and syllabus, and exam-related problem solving skills. In current school settings, these learning normally occurs in big classes of 30-40 students per class. However, such a “one size fits all” approach may not work effectively for everyone as different students proceed on their learning in different ways and pace. To address this problem, we develop the Self-Evolving Adaptive Learning (SEAL) system for personalized education at scale. This system can be found at https://www.qlassroom.ai and the demonstration video at https://youtu.be/bZN3Elmt7ms.

Keywords: Personalized Education · Adaptive Learning · Artificial Intelligence

1 Introduction

General education in primary and secondary schools is a crucial stage to build a strong foundation before diving deep into specialised subjects in colleges and universities. To excel in the current education system, students are required to have a deep understanding of knowledge according to standardized curriculums and syllabus, and exam-related problem solving skills. However, general education has long faced the tradeoff between quality and scalability. There exists a notable advantage of small-group tuition over group instruction. Nonetheless, group instruction with big classes of 30-40 students per class remains the norm in the current school settings. As a result, the effectiveness of teaching and learning is compromised as it is challenging for teachers to tailor personalized guidance to each student in such settings.

To address this problem, we propose the Self-Evolving Adaptive Learning (SEAL) system to allow personalized learning at scale, leveraging AI to solve the problem related to the trade-off between quality and scalability. Through AI, the solution we present is the ability to give customised reports and tailor-made study guides for each student. This way, we solve the problem of scalability, but ensure that students still have a personalised learning experience to give them the help they need. While our use case is currently for pre-tertiary education, the SEAL system will be useful for educators teaching any formal subjects or general topics.
1.1 Related Works and Systems

Most works on AI-enabled education focus on the automated assessment of student assignments, particularly those relating to programming exercises [1,4,3]. While assessment is an important aspect of education, they only measure student performance to some extent but do not personalize or influence how a student is able to acquire knowledge in specific subjects. eTutor [6] is a web-based system that aims to deliver teaching content to students in a suitable way to maximize their exam scores and minimize teaching time, based on their previously answered questions. Another system, AyudasCBI [5], approaches this problem as a recommendation problem, where they used a hybrid content-based and collaborative approach to recommend content to dentistry students and uses their explicit feedback on these content to evaluate its relevance.

Many AI-based education system aim to optimize a specific metric, e.g., final exam scores, and represent student profile via their answers on past questions. In contrast, our proposed SEAL system differs in the following aspects: (i) instead of individual questions making up a subject, SEAL models the syllabus based on a knowledge graph that represents the topics, sub-topics, questions and question difficulty, which is versatile and extendable to other subjects; (ii) instead of modelling student history based on past questions answered, SEAL uses a student knowledge profile adapted from the earlier knowledge graph and the student’s past performance, which allows us to better measure student competency in specific topics of that subject; and (iii) SEAL offers an intuitive analytics dashboard that enables students to understand their performance and potential knowledge gaps, and track their performance over time.

2 System Architecture

The SEAL system comprises three main components, namely: (i) a syllabus/question input component that allows the educator to enter details about the subject syllabus and associate questions with key learning outcomes; (ii) a lesson plan recommendation component that tracks a student’s learning trajectory and makes recommendation for a learning path (i.e., series of questions) to both fit the student’s ability and overall learning outcomes; and (iii) a performance analytics component that allows students to understand their own performance and educators to track the progress of their students. We further elaborate on each component next.

2.1 Syllabus/question input component. The main purpose of this component is to curate and construct the overall content corresponding to a specific subject, mainly the syllabus and questions. This component offers two main functionality, namely:

- Question input. SEAL offers a web-based interface for the educator to enter questions, their answers and assign appropriate tags to these questions. These tags could
correspond to details such as the difficulty level, main topic, sub-topics that the question belongs to. Figure 1 shows an example of this question input interface.

- **Syllabus representation.** Using the questions and associated tags from the earlier step, SEAL then build a knowledge graph that represents the specific subject, e.g., O-level Mathematics. This knowledge graph comprises topics within this subject, sub-topics belonging to each main topic, which in turn are represented by a set of questions tagged with varying difficulty. Figure 2 shows a generated syllabus based on this process.

2.2 **Lesson plan recommendation component.** This component aims to profile each student’s understanding of the subject over time, and make appropriate recommendations of learning paths in the form of questions that best steers the student towards a specific learning outcome. This component achieves these objectives in two steps:

- **Student knowledge profiling.** This sub-component profiles each student’s understanding of the subject at any given point of time, based on the knowledge graph constructed in the previous component. Each student is associated with their own instance of this knowledge graph, which is continuously updated as the student attempts the recommended questions.

- **Personalized learning recommendation.** Based on the current profile of the student, SEAL will make personalized recommendation of a learning path that best fits the ability of the student and the overall learning outcome to be achieved. This learning path is represented as a series of questions that are personalized in terms of both the types of questions and the order they are recommended. For example, a student who is strong in Topic A but weak in Topic B will be recommended less but harder questions about Topic A and more questions about Topic B ordered progressively in difficulty as the student answers the easier Topic B questions correctly.

2.3 **Performance analytics component.** This component aims to offer an analytical report on the performance of a student for a specific subject, as shown in Figure 3. This report comprises information such as the student’s performance on individual quizzes, ability to answer questions of varying difficulty, identification of areas/topics the student is weak in based on wrongly answered question, among other information. This component will enable students to understand their own performance and educators to track the progress of their students.

3 **Conclusion**

We proposed the SEAL system for personalized education, which comprises: (i) a syllabus/question input component for customizing education content to any subject;
(ii) a lesson plan recommendation component that models students’ knowledge profile, then recommends personalised content to achieve specific learning outcomes; and (iii) a performance analytics component that allows students to track their performance and progress over time. For future work, we intend to incorporate the active learning and design-thinking pedagogies into the SEAL system [2].

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