Enhancing Personalized Learning of Students through Deep Learning in an Adaptive Learning Environment.

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1 Introduction to E-learning

Education is one of the fundamental pillars in a society that drives intellectual growth and uplifts social standards. According to United Nations, Universal Declaration of Human Rights, Article 26, 'Everyone has a right to education' (UN General Assembly, 1948). At the beginning of the last century, education focused on knowledge and skills without considering the learner's expectations and learners abilities. Hence the 'one size fits all' education system faced challenges in catering to individual student requirements. Personalized teaching and learning frameworks immerged to fill this gap with the development of technology. Learning Management Systems (LMS), Adaptive Hypermedia Systems (AHS), and Intelligent Tutoring Systems (ITS) are to name a few systems developed to cater to personalized education. (Katsaris and Vidakis, 2021). Table 1 further explain each E-learning system.

Table 1 Types of E learning systems

E-learning systems	Characteristics
Learning Management Systems	LMS delivers content and help administrative tasks
Adaptive Hypermedia Systems	Provide content based on user goal and performance
Learning Style based Adaptive Educational Systems	Personalize the learning experience based on learning style (visual, auditory, reading/writing, and kinesthetic)
Intelligent Tutoring Systems	Provide immediate and customized instruction/feedback without human intervention using Adaptive Learning

This study focues in Intelligent Tutoring Systems. According to (Mousavinasab et al., 2021) Intelligent Tutoring Systems (ITSs) consist of four main modules. The first is the expert module, containing domain knowledge and problem-solving techniques. The second is the student diagnosis module, which gathers and updates information about the learner's knowledge, activities, and responses. The third is the instruction module, which detects knowledge deficiencies and employs teaching strategies to address them using adaptive learning technologies. The last module

is the user interface, facilitating communication between the user and the system. Incorporating AI techniques, e-learning systems have aimed to enhance adaptive and customized learning. Adaptive feedbakcs what makes intelligent tutoring systems really intelligent. This study further focues on the third instrudction models' adaptive learning capabilities and how to improve adaptive learning process using deep learning.

1.1 Introduction to adaptive learning

Adaptive learning is a methodology for teaching and learning that strives to personalize lessons, readings, practice activities, and assessments for individual students based on their current skills and performance. Adaptive learning systems use a data-driven approach to adjust the path and pace of learning, enabling the delivery of personalized learning at scale (Ennouamani and Mahani, 2018).

Adaptive learning is a type of scaffolding technique used in educational technology that is tailored to support all stakeholders in an educational institution, including teachers, students, and school administrators. According to (Jan-Martin Lowendahl et al., 2016) adaptive learning adjusts instructional content based on student responses and preferences, relying on learning data and algorithmic pedagogical responses.

1.1.1 Importance of adaptive learning

There are many benefits of adaptive learning. Adaptive learning saves teachers time and provides data and analytics that help to understand students. For students, it provides a personalized learning experience better suited for their capacity and instant feedback. School administrators can improve student performance, such as pass rate and proficiency. Clark, Kaw and Braga Gomes, (2022) advise adaptive learning give best results when it combined with pre class sessions.

Ennouamani & Mahani, (2018) have summarized adaptive learning systems to 3 models. They are Learning model, Adaptation model and Domain model. The learner model contains the student characteristics such as learning style, reasoning style, interests and student performance history. The domain model contains knowledge of the studying domain, study materials and learning objectives. The adaptation model has adaptation rules that align with the student performance and domain. It asses the student behavior and navigates them to relevant materials in the domain model.

A sophisticated adaptive learning system temporally updates its rules and gets feedback from external and internal learning environments. As shown in the Figure 1-1 adaption model feeded by the leaner model and domain model. Then it provide adaptive feedback to the system. System interact with the leaner via graphical user interface. Adaptive model could suggest learner to attempt a easy or hard question, spend more time on basics or take a brake and start learning later.

Adaptive learning positively impacts student performance with empirical evidence, but it depends on the design of the adaptive learning system (Liu et al., 2017). It should be user-centric, and content must properly align with the learning outcomes. An adaptive learning system should be able to provide meaningful feedback and navigate students only to the relevant content.

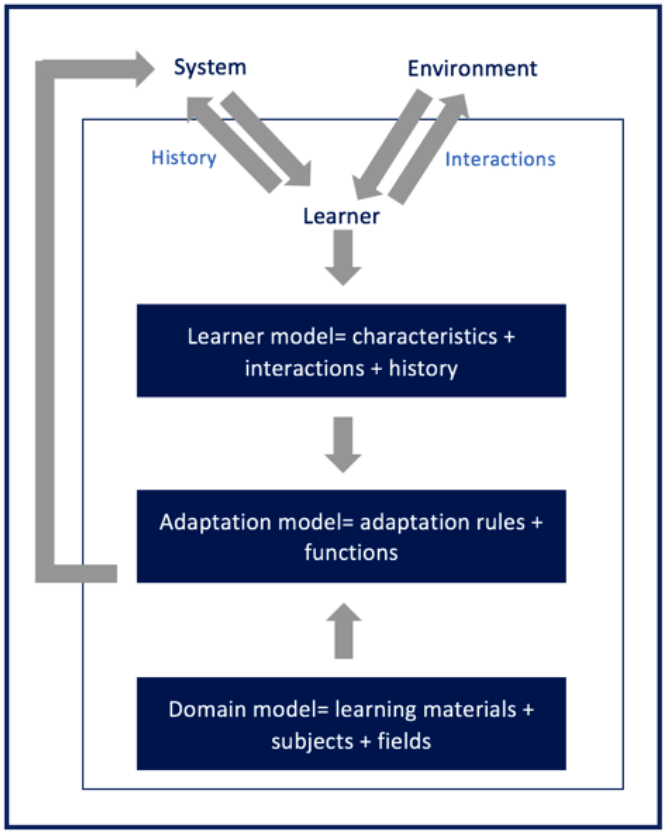

Figure 1-1 Adaptive e-learning systems' components (Ennouamani and Mahani, 2018)

According to (Martin et al., 2020), when educational institutes adopt adaptive learning methods, they face three challenges with respect to technology, instruction, and management. There are technological barriers when schools connect existing learning management systems to adaptive learning methods, real-time data-sharing challenges, and the complexity of adaptive systems. Teachers and instructors not having enough experience can lead to the adaptation of adaptive learning methods. Educational institutions must train and monitor how well they adopt adaptive learning methods. Sometimes educators resist adopting adaptive learning methods due to differences in the curriculums, additional workload, or not having confidence that adaptive learning methods can improve students' knowledge state. Lack of management support can also lead to adaptive learning method adoption failure. Incompatible organization goals or lack of leadership and insufficient human resources and financial resources can also cause to halt the implementation of adaptive learning systems.

1.2 Research problem

This research studies data sets from a real-world commercial adaptive learning platform. It provides practice questions and assignments targeting science and mathematics school curricula. Practice questions are called Goals on this platform. Each goal consists of multiple answer questions related to learning objectives. If a student gives the correct answer student will be allowed to proceed to the next question. If the student fails the question, he or she will get a new question or be presented with the study materials to refresh their knowledge.

This platform measures the mastery of a student using a modified version of Item Response Theory (IRT) (F. M. Lord, M. R. Novick and Allan Birnbaum, 1968), which is a statistical technique. This method consider only the questions difficulty ,student proficiency and skill discrimination ability of the question. Students ability to answer a question correctly depends on stundets mastery level on the skill represent by the question. But most of the skill have prerequisite skills. Exiting model does not consider the mastery level of prereuqisit skills. Subjected adaptive learning platform has not assessed the impact of study materials. Existing model does not consider the impact of study materials towards students performance. Hence there is requirement to explore novel method to measure students mastery level considering prequisits skill and study materials impact.

Current system provide lots of value informations to teachers such as mastery level achived by the students and the degree of effort each student have to put to reach the mastery level. This helps teachers to undestand individual students learning rate. If students are clustered based on the learning rate, teachers can analyze the class separate clusters and identify common poor skills among student clusters. This will help teachers rather than spend time on individual stundets weak areas, spend time one multiple students who has common weak skills.

1.3 Research gap

In literature, knowledge tracing is widely researched under many branches. In the early stages, Bayesian knowledge tracing (KT) was the most popular method for knowledge tracing method. Later IRT was introduced, and recently with the boom of deep learning, deep knowledge tracing was introduced. DKT outperformed all previous techniques, and there are many applications under all the branches. They predict students' ability to answer a question correctly, recommend learning materials or questions, assess the quality of the education, and many more.

When our data set is compared to the literature, our data set also has the sequence of questions under different learning objectives and the correctness of the answers like in other studies. One specialty in our data set is, middle of the question sequence, students referred to learning materials if they have poorly performed for the related learning objective , and attempted again. In the previous research work study materials are not included in the research problem. This can be used to measure the quality of the learning materials and how it impacts each student. Additionally, we attempt to incorporate question difficulty into the problem formulation.

In terms of learner characteristics, this research analyzes the possibility of clustering the students based on their prior knowledge and performance. The proposed study will also analyze the impact of study or the instruction materials provided to shape the leaners characteristics.

1.4 Research question

1. What factors influence students’ personalized learning experience within an adaptive learning environment?

2. How does choice of learning materials affect students' personalized learning experience in an adaptive learning environment?

1.5 Research objectives

1. Identify the factors that influence personalized learning experiences in an adaptive learning environment.
2. Evaluate the effectiveness of study material utilization towards improving student mastery level.
3. Explore the potential of deep learning techniques in enhancing personalized learning experiences for students.

1.6 Research scope

The scope of the study is to analyzes a real-world dataset from an adaptive learning platform. It focuses on student coursework performance, assignments, learning objectives and knowledge graphs. The scope is to cluster stundets based on performance and predict the mastery level of students.

2 Data

This research uses a real-world data set from an International E-learning (courseware) platform that uses state of the art adaptive learning technology. This platform provides educational content targeting schools for Mathematics, Economy, Chemistry, Biology, Physics and Psychology. Based on the research question, identified data was already collected with the organization’s approval.

Subjected Adaptive Learning Platform (ADP) measures the learners' progress level ranging from 0 to 100. Teachers can assign assignments to the student related to a specific Learning Objective(LO). A student has to reach 100 progress to complete the assignment, then the student has achieved the ‘Mastery’ to that LO. Each LO has minimum 4 question, progress of a student for a given LO is

Progress = proficiency score x fraction of the minimum questions learner have tried

If student fail master a LO, student get to do more practice questions. If the student need further support, he or she get more instructions and direct back to the prerequisite LOs.

All the learning objectives, concepts, questions, and course materials are associated to knowledge graphs. These knowledge graphs and progress levels drive the students journey to master a given learning objective. But other characteristics of the student joinery are not considered. Such as time spent on a question, time spent on instructions, quality of the instruction materials, etc.

Table 2 Data and attributes

Data	Number of data points	Attributes
Student coursework performance	3.3 million	• Learning objectives • coursework id • user id • progress • question id • correctness of the answer • time spent to answer • time spent for the question instruction • study material id referred
Student assignment	140,000	• Learning objectives • test id • user id • question id • correctness of the answer
Learning objective map (knowledge graph)	1145	• Source LO Id (prerequisite LO ID) • Destination LO Id • Source LO Title (prerequisite LO Name)

		• Destination LO Title

3 Research Methodology

The research methodology for this study will follow a constructive research approach, aiming to analyze and understand the relationship between student performance, learning objectives, study materials, and learning progress. The steps involved in the research methodology are as follows:

Data Collection: The required data has already been collected for analysis purposes.

Data Processing: The collected data will be transformed into a tabular format, where data types will be adjusted, and values will be replaced for ease of analysis.

Data Analysis:

a. Mapping Student Performance: Student performance will be mapped with direct learning objectives, prerequisite learning objectives, and study materials to establish connections and patterns.

b. Graph Development and Cluster Analysis: Graphs will be developed to represent student performance and learning objectives. These graphs will then be clustered to identify groups of students with similar behavior.

c. Cluster Analysis: The identified student clusters will be analyzed and compared to understand their performance and differences in relation to other clusters. The analysis will focus on:

i. Impact of Study Materials: Assessing how study materials impact student performance within each cluster.

ii. Learning Rate Comparison: Comparing the learning rates among different clusters.

iii. Impact of Prerequisite Learning Objectives: Investigating the influence of prerequisite learning objectives on the progression to subsequent learning objectives.

iv. Relationship between Learning Effort and Progress: Exploring the relationship between learning effort (e.g., time spent, number of questions answered) and learning progress.

Prediction of Students' Answer Correctness: Predictive models will be developed to forecast students' answer correctness based on the analyzed data.

Evaluation of Students' Mastery Level: Students' mastery levels will be evaluated based on their answer correctness and the established criteria.

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