Enhancing Personalized Learning of Students Through Study Material Recommendation in an Adaptive Learning Environment

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Introduction

E-learning

▶ E-learning Personalized teaching and learning frameworks immerged to fill the gaps in teacher centered educations system

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**

Introduction

Adaptive learning

- ▶ Adaptative learning is a range of tools and techniques to personalize the learning experience for students
- ▶ As an example for the same learning objectives two students get different number of question and instruction depend on the knowledge level
- ▶ It provides valuable insights to teachers and administrators
- ▶ There are three main components in an adaptive learning system
  - ▶ Learner model
  - ▶ Adaption model
  - ▶ Domain model

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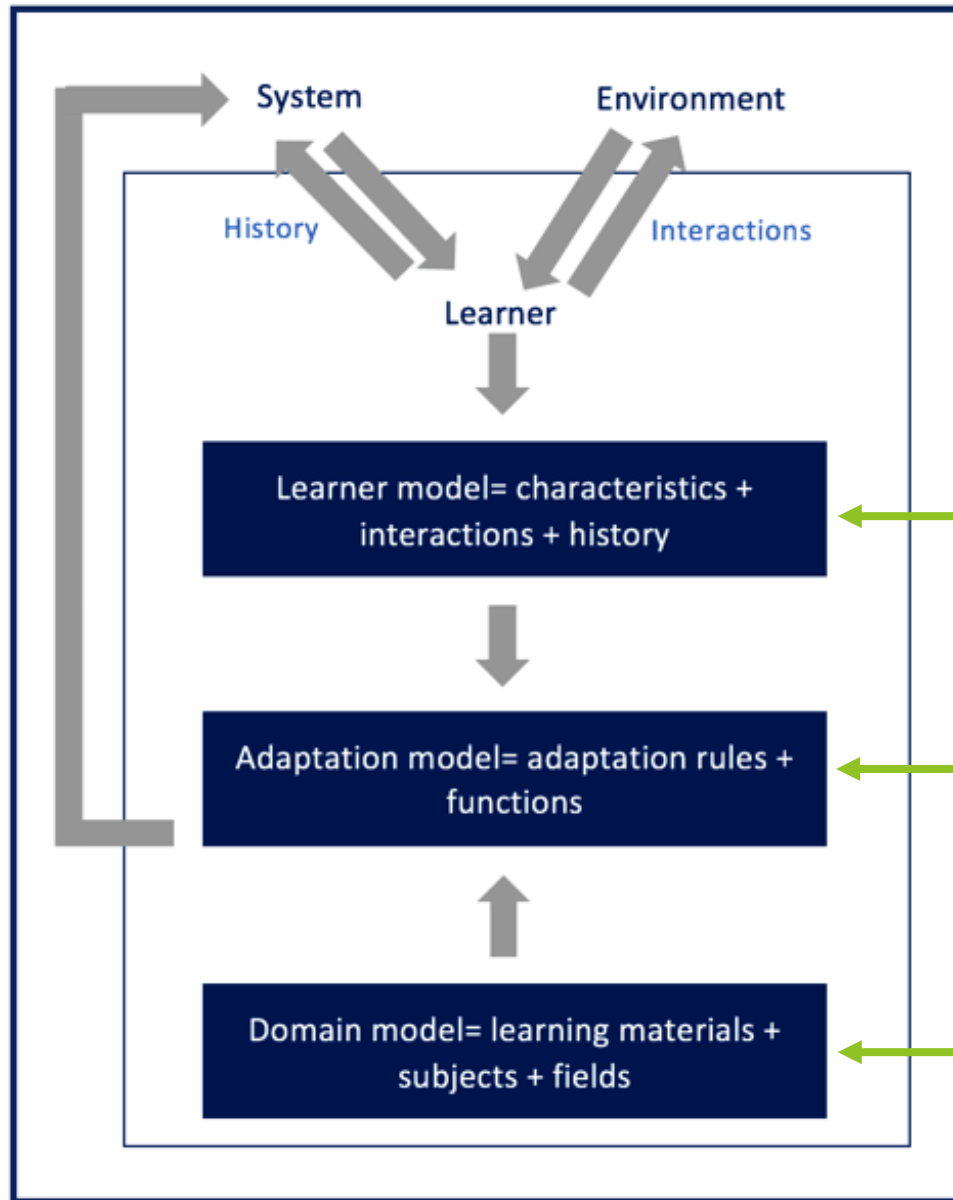
Learner model collects data

adaptation model adjusts the learning experience through **knowledge tracing**

Represents the knowledge being taught in adaptive learning

Knowledge Tracing
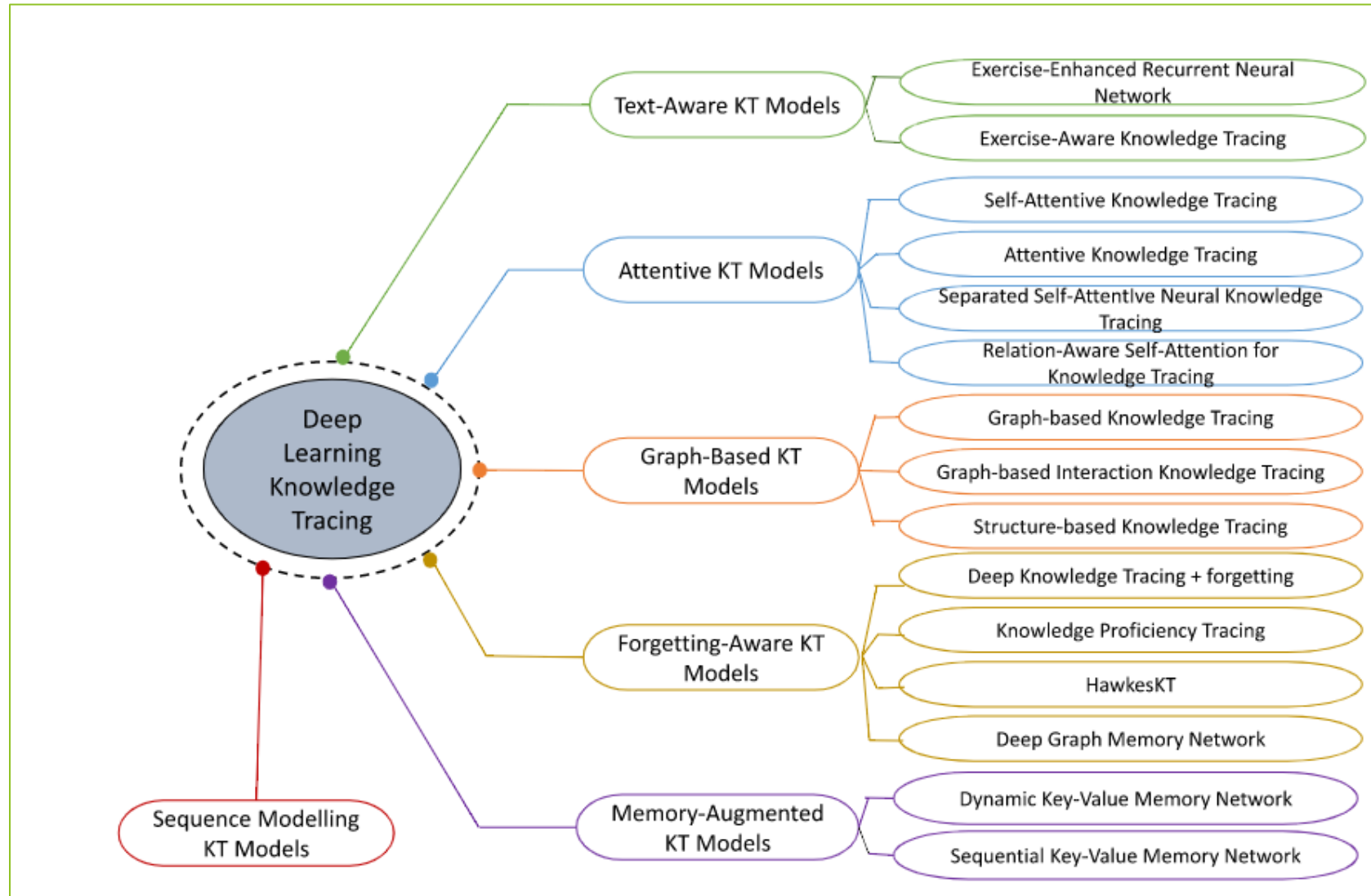
- Knowledge Tracing is a machine learning technique that models a student's mastery of concepts over time.

- There are two branches of knowledge tracing. They are
  - Traditional knowledge tracing - Statistical techniques
  - Deep knowledge tracing – Deep learning-based techniques
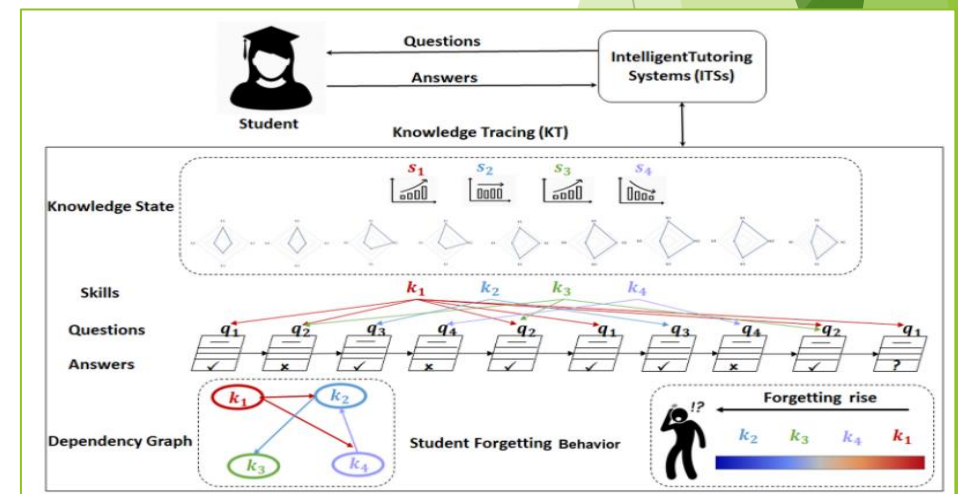
Traditional Knowledge Tracing
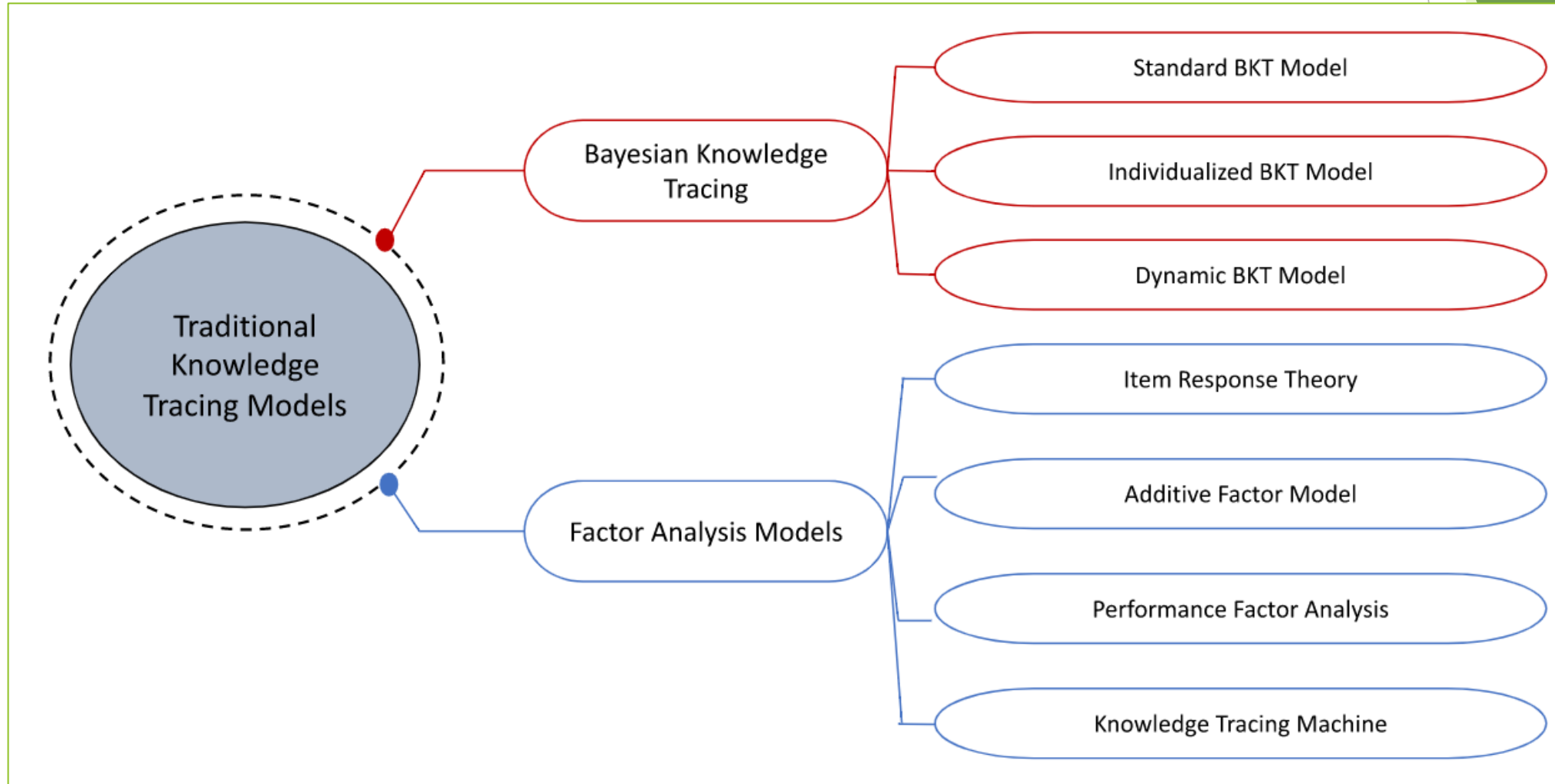
Deep Knowledge Tracing

Learner Characteristics

▶ **Learner characteristics** are the main inputs of knowledge tracing methods.

▶ Based on the collected data set this study focus on **Performance** and Prior **Knowledge** . They can measure through

  ▶ **Mastery and correctness of answers**

  ▶ Previous grades

  ▶ Rank

  ▶ Previous experience with the course content

  ▶ Prior credits

  ▶ course repetition.
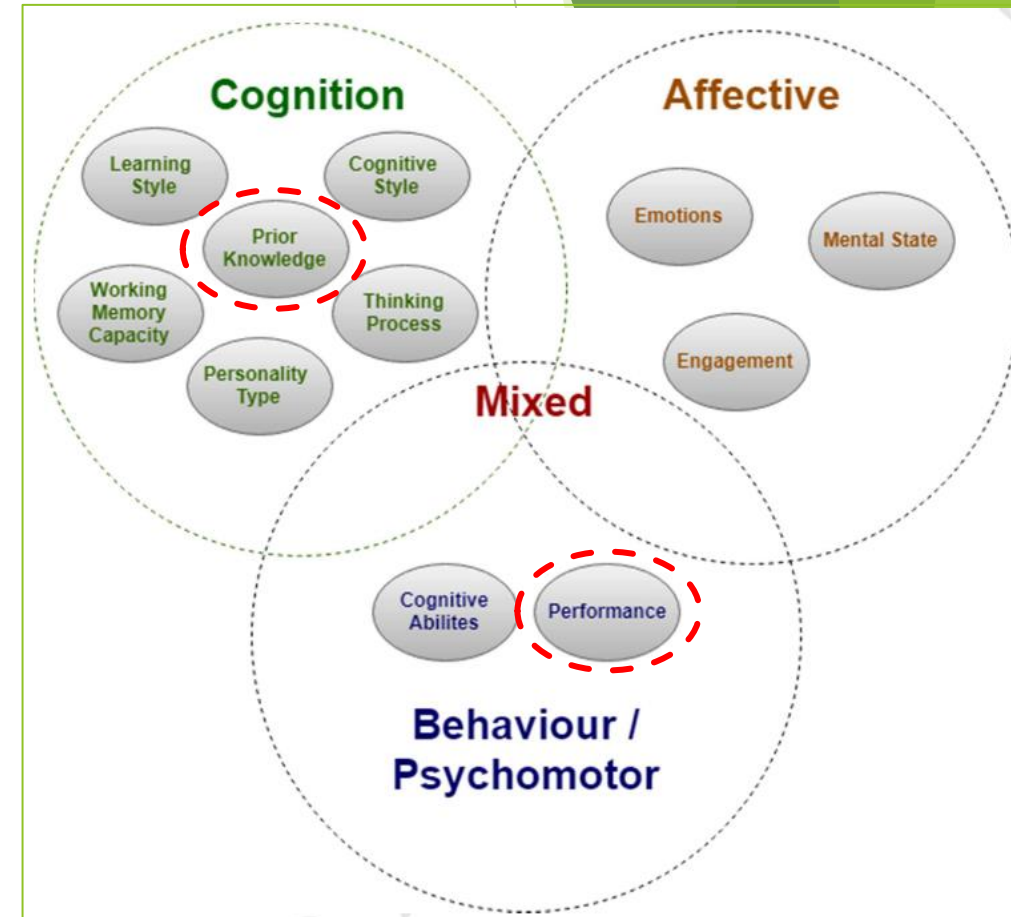
(Afini Normadhi et al., 2019)

Literature Review

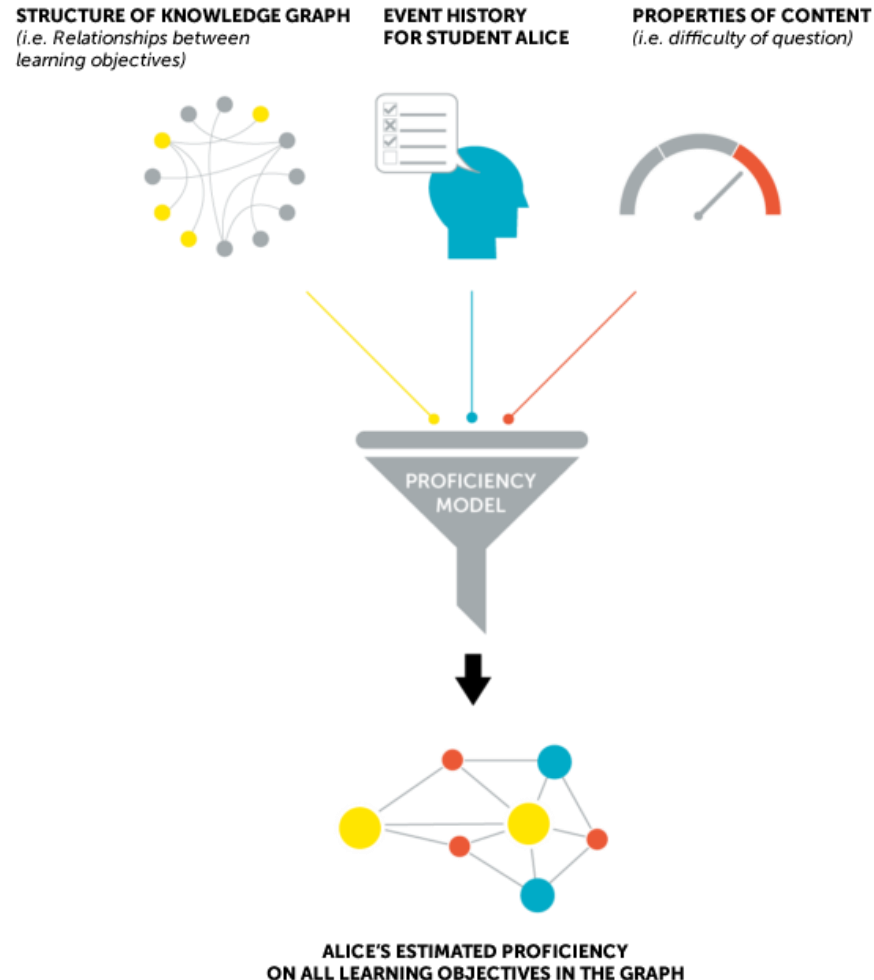| Domain	Research topic	Approach and findings
Adaptive learning	Adaptive learning: Helpful to the flipped classroom in the online environment of COVID? (Clark, R.M., Kaw, A.K. and Braga Gomes, R.,) 2022	Conducting a comprehensive survey on knowledge tracing by categorizing methods, identifying datasets and their performance, exploring possible application areas, and discussing future research directions
Adaptive learning	An overview of adaptive e-learning systems (Ennouamani, S. and Mahani, Z) 2018	Literature review on adaptive learning systems
Adaptive learning /Recommendation	Towards an adaptive learning framework for MOOCs (Ardchir S,Talhaoui M,Azzouazi M) 2017	Developed a personalized learning pathway recommendation system for Massive Open Online Courses based on user competency.
Deep Knowledge Tracing	Deep Knowledge Tracing (Piech, C., Bassen, J., Huang, J., Ganguli, S., Sahami, M., Guibas, L., Sohl-Dickstein, J) 2015	Introduced deep knowledge tracing using deep learning for the first time. Overperformed traditional methods

Domain	Research topic	Approach and findings
Deep Knowledge tracing	Structure-based knowledge tracing: An influence propagation view (Tong, S., Liu, Q., Huang, W., Huang, Z., Chen, E., Liu, C., Ma, H. and Wang, S) 2020	Add temporal and special dimensions to deep knowledge tracing. Measured knowledge statues of multiple learning objectives at once
Knowledge Tracing	A Survey. *ACM Computing Surveys*(Abdelrahman, G., Wang, Q. and Nunes, B). 2023.	The work provides a survey on knowledge tracing, including methods, datasets, applications, and future research directions, summarizing 134 studies
Learner Characteristics	LEARNER CHARACTERISTIC BASED LEARNING EFFORT CURVE MODE: THE CORE MECHANISM ON DEVELOPING PERSONALIZED ADAPTIVE E-LEARNING PLATFORM. (Hsu, P) 2012	Model and identified 16 learning curve types. These curved can use to identify support need students and degree of support
Learner Characteristics	Clustering children's learning behaviour to identify self-regulated learning support needs (S.H.E. Dijkstraa, M. Hinneb, E. Segersa, I. Molenaar) 2023	Model and identified 9 learning curve types using statistical methods. Assessed how learning curve changed after studying

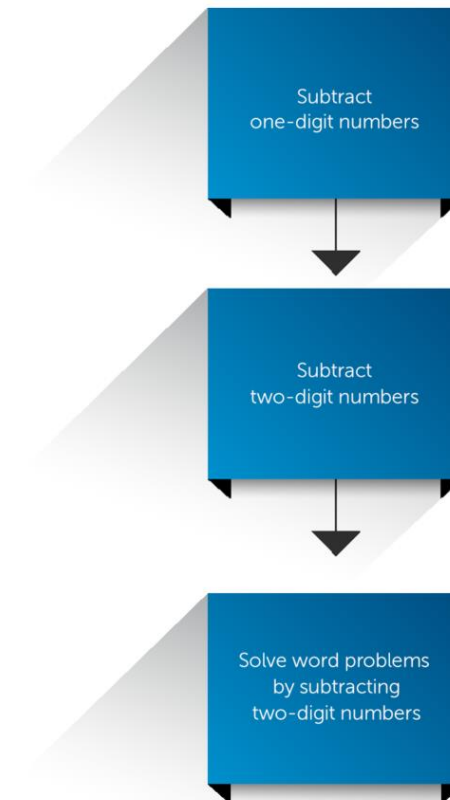| Domain	Research topic	Approach and findings
Recommendation System	Recommending Learning Objects Based on Utility and Learning Style (Borges, G. and Stiubiener, I) 2014	Recommend suitable learning objectives based students learning style and performance
Recommendation System	Personalized Links Recommendation Based on Data Mining in Adaptive Educational Hypermedia Systems (Duval, E., Klamma, R. and Wolpers, M.,) 2007	Recommend study materials based on pervious web site usage. Do not consider stundets performance is a weakness
Recommendation System	Using Simulations to Evaluate the Effects of Recommender Systems for Learners in Informal Learning Networks (Hendrik Drachsler, Hans Hummel and Rob Koper)	The work includes a model and flow chart of the simulation, outlines the collaborative filtering techniques to be investigated, and presents the experimental design for testing recommender systems in informal learning networks.

Introduction to the Studying Adaptive Learning System

Sample knowledge graph

![Knewton - A Wiley Brand]

- Knewton is an adaptive learning company

- It provide personalized educational content

- They use modified version of Item Response theory

STRUCTURE OF KNOWLEDGE GRAPH
(i.e. Relationships between learning objectives)

EVENT HISTORY FOR STUDENT ALICE

PROPERTIES OF CONTENT
(i.e. difficulty of question)

PROFICIENCY MODEL

ALICE'S ESTIMATED PROFICIENCY ON ALL LEARNING OBJECTIVES IN THE GRAPH

Subtract one-digit numbers

Subtract two-digit numbers

Solve word problems by subtracting two-digit numbers

Introduction to the Studying Adaptive Learning System

Set Goal (assignments)

Goals are homework set by the instructor related to set of learning objectives

Assess students' knowledge state

After each question, based on the correctness of the answer, student's knowledge state is estimated using a statistical method

Recommend next activity

Based on the knowledge statues recommend next item to the user (difficult or easy item / study material)

Research gap

▶ Despite the vast literature on knowledge tracing, there is a need for further exploration on the application of different methods in educational settings.

▶ Previous studies clustered students learning curve based on score but not based on the mastery level

▶ Previous studies haven't compare learning curve clusters with other characteristics such as time spend for a question, time spent on instructions and quality of the study materials

▶ Under deep knowledge tracing, no study have assessed the impact of presenting study materials middle of the question sequence

Research Questions

1. What are the factors impact students personalized learning in an adaptive learning environment?

2. What is the impact of learning materials on students personalized learning in an adaptive learning environment ?

Research Objectives

1. Identify the factors that influence personalized learning in an adaptive learning environment

2. Evaluate the effectiveness of study material recommendations in improving student learning outcomes.

3. Predict students' mastery using Deep Learning when study materials presented middle of the question sequence

4. Explore the use of machine learning algorithms for study material recommendation in an adaptive learning environment.

Research Methodology - Data

- Data collection – Required data is already collected and further

- Data is from a commercial adaptive learning system

- Data contains students' performance under 'Applied Mathematics' curriculum and related knowledge graphs

Data

Data Set	Number of Data Points	Attributes
Student coursework performance	3.3 million	- Learning objectives - question id and study material id - Answer correctness and mastery level - time spent to answering and instructions
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

Research Methodology

▶ Data processing
  ▶ Handle null values
  ▶ Pivot student mastery to learning curves
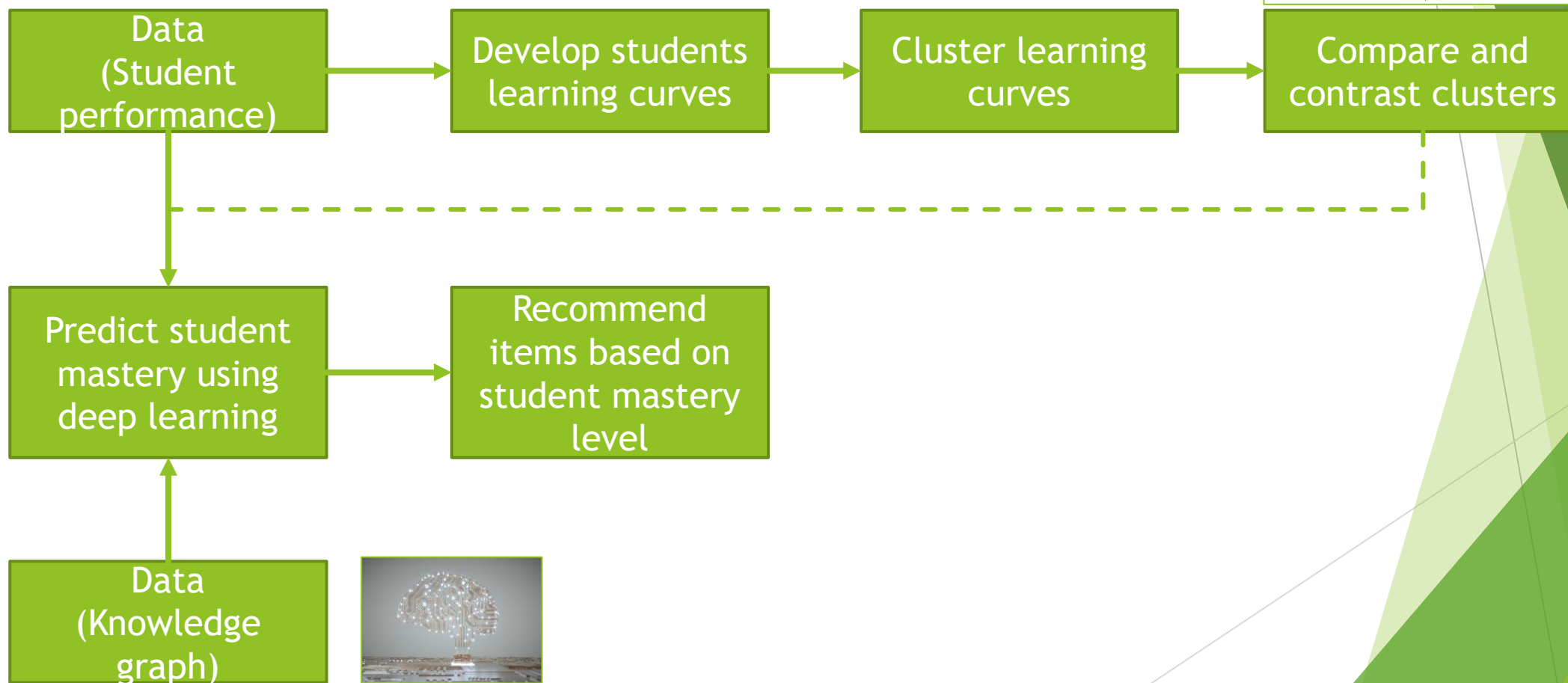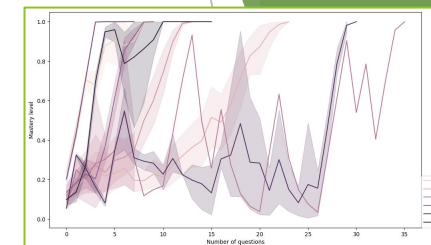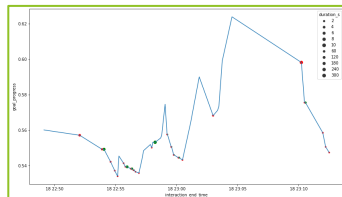 ▶ Develop knowledge graphs (networks) from tabular data

▶ Algorithms
  ▶ Clustering algorithms
  ▶ Deep learning
  ▶ Recommendation algorithm

▶ Evaluation
  ▶ Evaluate mastery prediction based on correctness of answers

Research Methodology (summary)

Data (Student performance)	→	Develop students learning curves	→	Cluster learning curves	→	Compare and contrast clusters

Predict student mastery using deep learning → Recommend items based on student mastery level

Data (Knowledge graph)

Timeline

	April				May					June				July				Auguest				September				October				November				December			
	3-Apr	10-Apr	17-Apr	24-Apr	1-May	8-May	15-May	22-May	29-May	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep	2-Oct	9-Oct	16-Oct	23-Oct	30-Oct	6-Nov	13-Nov	20-Nov	27-Nov	4-Dec	11-Dec	18-Dec	25-Dec	1-Jan
Project proposal	■	■	■	■																																				
Data analysis (identify learner characteristics)					■	■	■	■	■	■	■																													
Asses the impact of study materials												■	■	■	■	■	■	■	■																					
Interim presentation																																								
Study material recommendation engine building																				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Demonstration																																								
Final thesis submission																																					■	■	■	

Thank You

Q & A

Appendix - Sample Learning Curve

- Questions
- Instructional materials
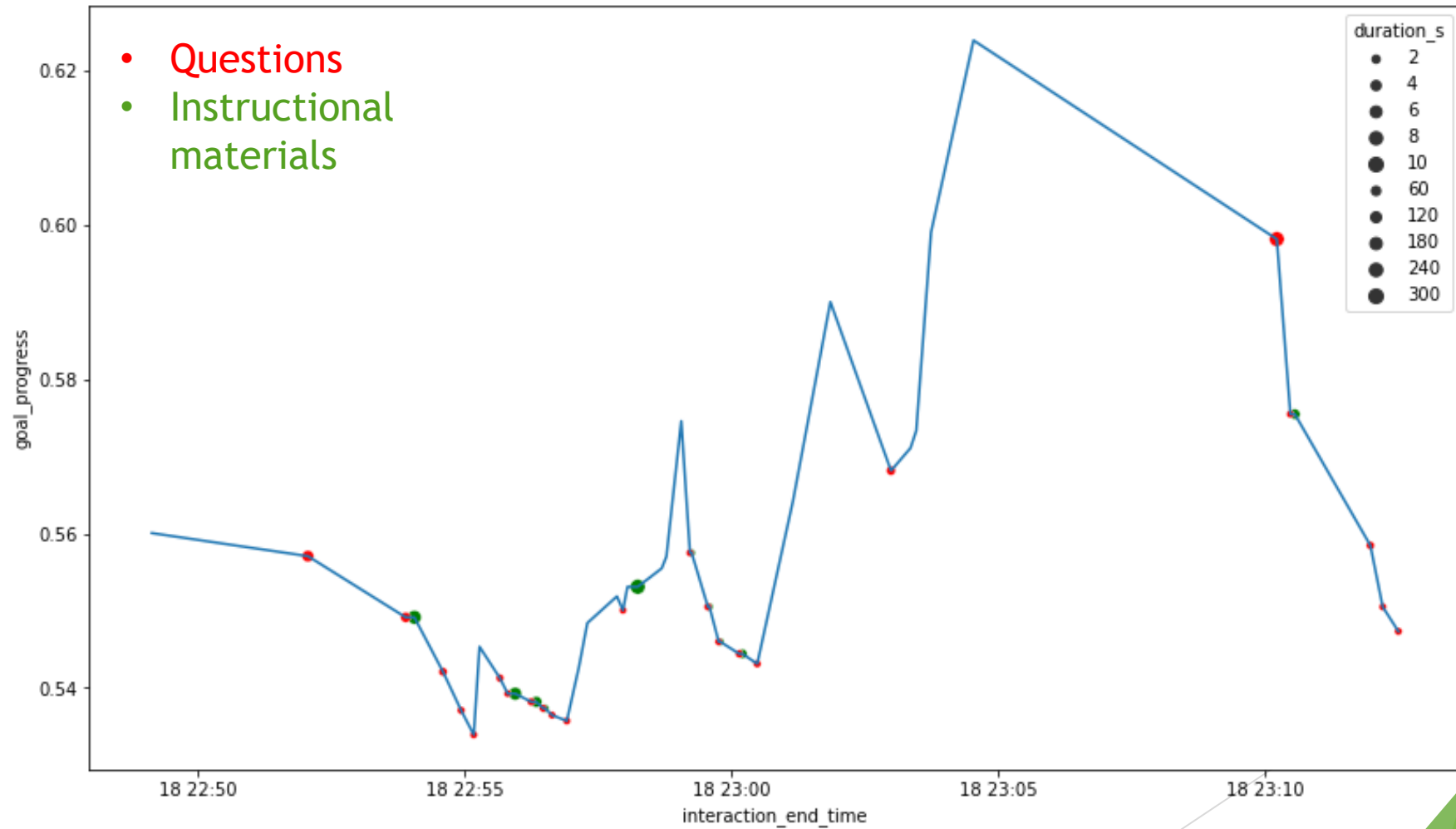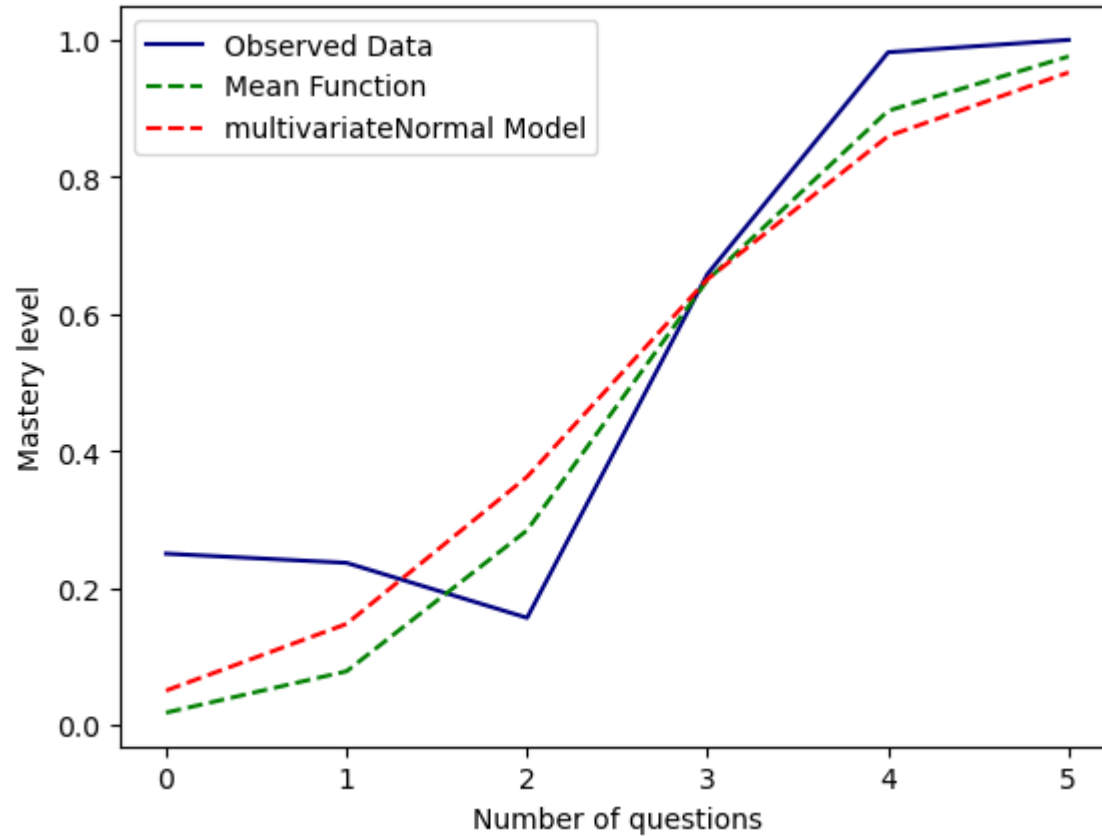
Appendix - Clustering Learning Curves (ability cure)
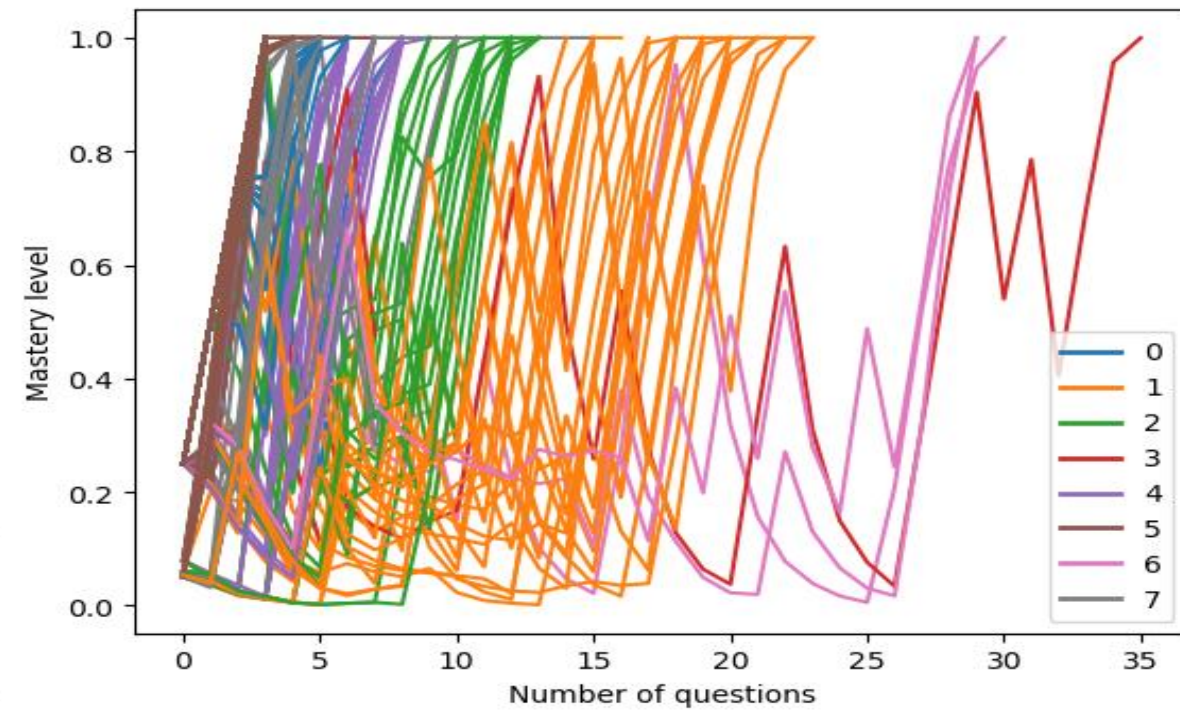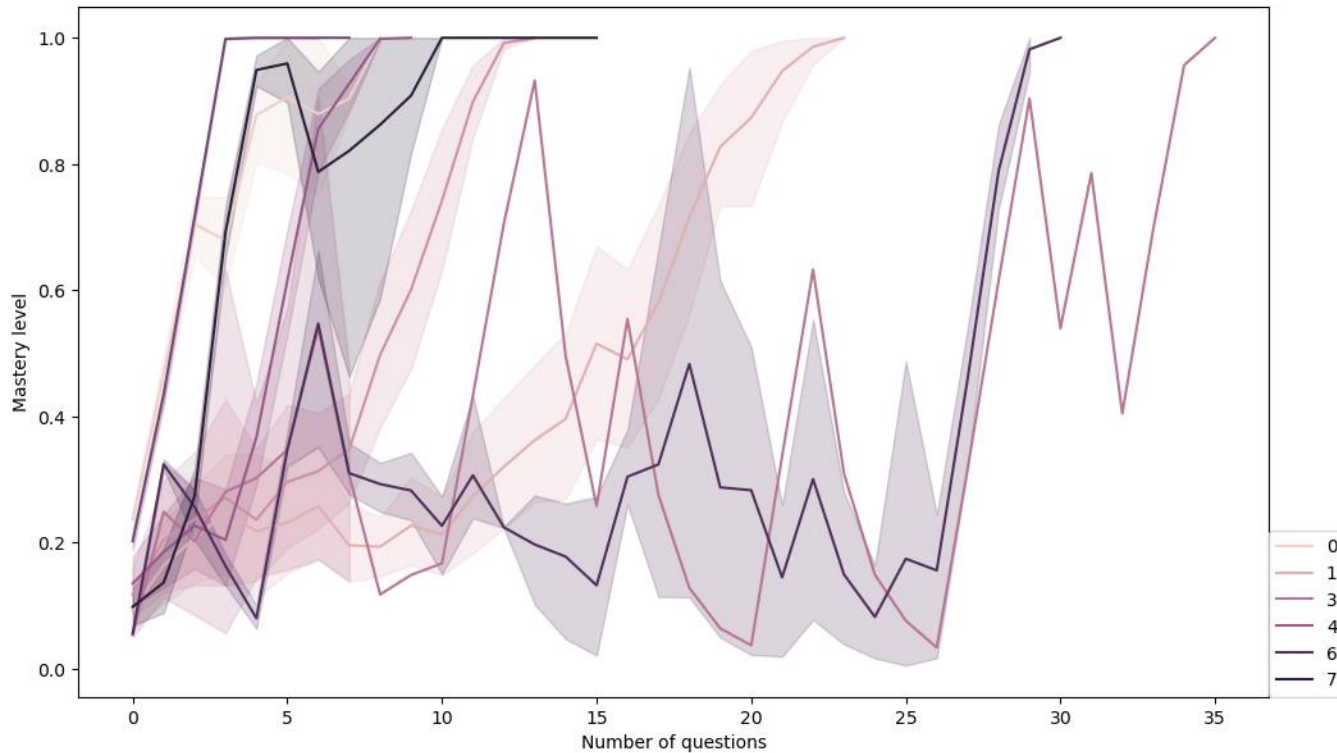
Appendix - Modeling student ability Curve

$$\mu_h(x) = \max\left(0, \frac{2\,y_{\max}}{1 + \exp\left(-\frac{x - \kappa_h}{\lambda_h}\right)} - y_{\max}\right).$$

$$k_h(x, x') = \tau_h^2 \exp\left(\frac{\|x - x'\|^2}{-2\ell_h^2}\right)$$
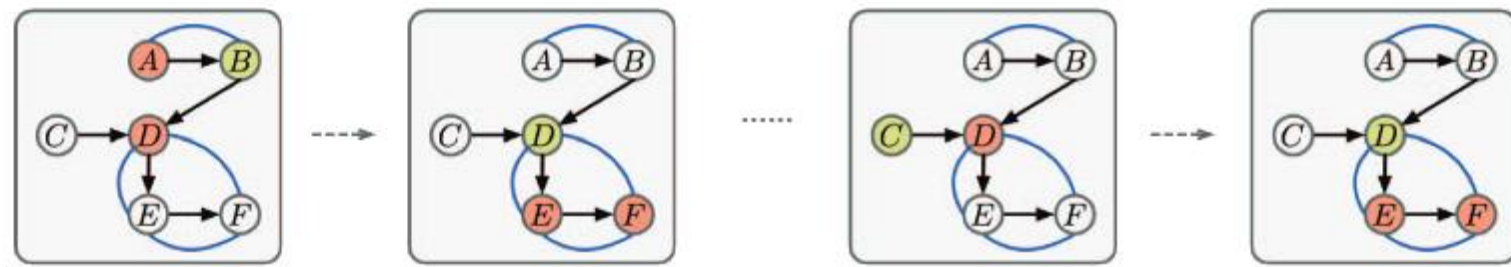
(Dijkstra et al., 2023)

Deep knowledge tracing

Research problem

Introduction to studying adaptive learning system

▶ Set goals for the student's work session (like a homework assignment) and/or the whole educational context (like a course). This frequently involves an instructor creating a syllabus or assigning some learning objectives.

▶ Deliver assessment questions relevant to those goals.

▶ Estimate the student's knowledge state based on the correctness of their answers, the difficulty of the questions, and/or the alignment of the questions to a knowledge graph of skills, concepts, or learning objectives.

▶ Decide what activity should come next based on the student's estimated knowledge state—whether that means delivering easier or harder questions, providing an instructional intervention, remediating a gap in prerequisite knowledge, suggesting the student speak to their teacher, or some other activity.

▶ The cycle of steps (two to four) then continues until each student reaches the goals set in step one.