Mara Mih
Email: m.i.mih-1@student.tudelft.nl
Professor: Bernd Dudzik
Supervisor: Vandana Agarwal

Surveying Usage of Learning-Related Information in Adaptation for Intelligent Systems

1.Background

Learning is the ability to acquire new information and change behaviour over time based on that information. This also includes training and the development of skills.

Motivation

With the rapid growth of personalised systems and online education, there is a need to understand how these systems leverage human-specific data. There are multiple studies done on what factors can influence learning. Some examples are emotions, moods, prior knowledge, and behaviour. Because of this, current literature is mostly focused on identifying when a person is learning. In contrast, little is known about what kind of systems use learning information and how they recognise it. There are reviews done on pedagogical tools and technologies that aid language learning, but they fail to cover the entire scope.

Objective

This review is meant to cover this gap and analyse all systems that use learning-related information, including educational tools, assistive tools, and training aids.

2. Research Questions

How do intelligent systems use learning-related information to adapt their behaviour?

To answer this question, seven sub-questions were introduced. They focused on the type of inputs these systems use, the type of system presented, the application domain, the objective and motivation behind the system, the challenges presented, and any visible trends in the selected papers.

3. Methodology

The research question will be addressed by conducting a **systematic literature review (SLR)**. The aim is to systematically collect and analyse studies investigating how learning-related information is collected and used for adaptation in intelligent systems.

Process Steps

Search protocol → Abstract and title screening → Selecting full-length papers → Data extraction

Search Engines: Scopus, Web of Science, IEEE Xplorer

Exclusion Criteria: All non-English papers that model a user state or only identify when the user is learning, or are a literature review.

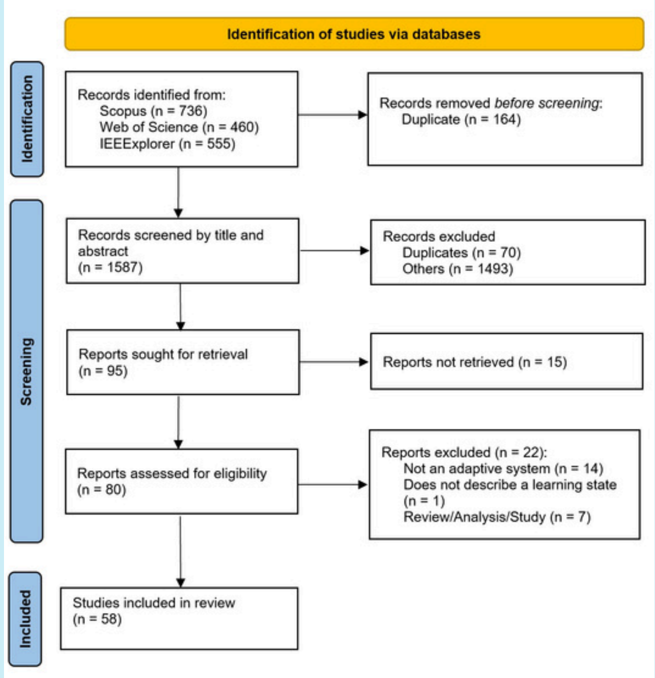
Inclusion Criteria: All Computer Science papers, describing an adaptive system that uses learning information in its adaptation.

Feasibility Criterion: Due to the time frame, only papers published after 2023 were included

Query: The query was create using **adaptive system**, **user modelling**, **learning**, and **education** as the core concepts.

The **final paper** was structured using PRISMA guidelines.

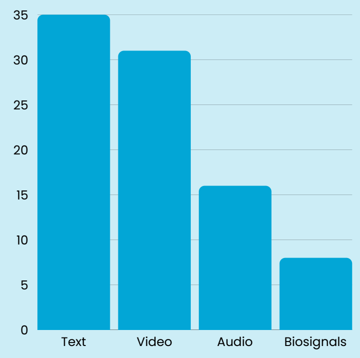
4. Data Analysis and Search Results



Extracted data

- System type: e-learning platform, XR environment, serious game, etc.
- Input type: text, audio, video, biosignal
- What did the system measure: facial emotions, gestures, speech patterns, etc.
- How does the system adapt? It gives recommendations, feedback, and changes content, etc.
- System objective: improve engagement, enhance learning outcomes, etc.
- Application domain: education, fitness, etc.
- System challenges: limited sensing abilities, limited domain coverage, etc.
- Other observed trends and patterns

5. Results and Discussion



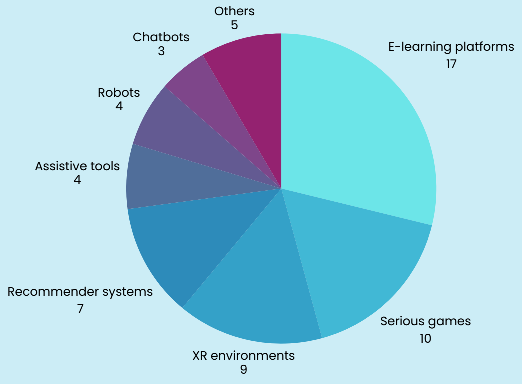
Input types

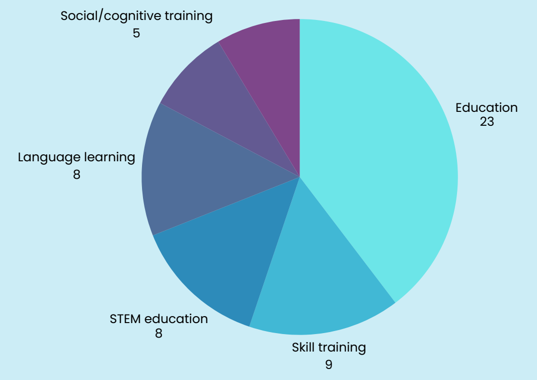
Half of the 58 included papers proposed systems that use multimodal inputs, usually combining two or three categories. Systems that used **text** input measured facial expressions, gestures, behaviours (like raising hands) and eye gaze estimation. The systems that measured facial emotions focused on frustration, confusion, boredom, attention and engagement. The eye gaze was used in language learning platforms to determine reading comprehension, and the gestures were used for XR environments to determine the user's movements.

Text inputs were mainly used for systems that accounted for user preferences and direct feedback. They were also used in language learning platforms to determine the user's progress. **Audio** inputs were used for systems with dialogue functions and for recording speech patterns for language learning. EEG signals were the main form of **biosignals**, and they were used to determine the user's engagement.

System types

The majority of the systems were **e-learning platforms** which combined multiple functions, such as recommendation, feedback, and real-time content changes. The analysed **recommender systems** gave suggestions for the optimal learning path or offered breaks when the user was not engaged anymore. **XR environments** were used for training motor skills, or skills that required a specific environment, such as public speaking. **Assistive tools** were created for people with cognitive or physical impairments, such as hard-of-hearing people.





Application domains

There was a range of educational and training domains. However, the majority did not specify the subject area, implying they are suited for multiple disciplines.
A diverse domain was **skill training**, which included systems helping with medical training (IV placement), public speaking, and routine development for children with special needs.

Language learning platforms focused on enhancing the learning outcome using audio and text inputs and adapting to the user's progress and knowledge. **Alternative education** platforms focused on non-traditional learning contexts, such as aiding students with ADHD in staying motivated while learning or giving interactive lessons and text-to-speech support for blind people. **STEM education** platforms focused on providing help with mathematics and programming.

Objectives

The overall objective of these systems was to enhance the learning experiences by increasing motivation and engagement. For example, some serious games modify the game difficulty based on the user's progress and knowledge. Another objective was to mimic face-to-face teaching in situations where it is crucial to student development. Some systems focus on reducing anxiety in high-stress situations or simulating realistic routines.

Challenges

Most systems did not explicitly mention their challenges, but out of the ones that did, a common limitation was the narrow range of emotions recognised. Some systems only classify emotions as positive and negative, losing nuances specific to human behaviour. Another challenge was the application domain since a part of the educational platform only supported specific subjects. Additionally, some papers that measured biosignals mentioned that their system could benefit from a broader range of sensors.

6. Conclusion and Future Work

The results show that most learning-related data systems were designed for education or training. In the **educational context**, most systems do not specify a particular domain, thus indicating that these systems can be flexible and adapted to a wide range of topics. The educational platform mostly follows the same pattern: identify the user state and modify the content or approach to keep the user motivated and engaged.

Training systems focused on improving motor skills use XR environments or serious games to create an interactive learning environment. The training systems had more variety, and were more detailed and unique ways in which they can be included in day-to-day life.

In the future, this review can be a basis for additional work on the topic. Further research can be done by removing the feasibility constraints and analysing a larger set of papers. Additionally, including experts with backgrounds in education or psychology could enhance the data interpretation when analysing the implications of the systems