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AI-Based Adaptive Learning: A Systematic Mapping of the Literature

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Abstract: With the aid of technology advancement, the field of education has seen a noticeable transformation. The teaching-learning process is now more interactive and is no longer restricted to students' physical presence in the classroom but instead makes use of specialized online platforms. In recent years, solutions that offer learning routes customized to learners' needs have become more necessary. In this regard, artificial intelligence has served as an excellent answer, allowing for the building of educational systems that can accommodate a wide range of student needs. Through this paper, a systematic mapping of the literature on AI-based adaptive learning is presented. The examination of 93 articles published between 2000 and 2022 made it possible to draw several conclusions, including the number of adaptive learning environments based on AI, the types of AI algorithms used, the objectives targeted by these systems as well as factors related to adaptation. This study may serve as a springboard for further investigation into how to address the problems raised by the current state.

Keywords: Adaptive learning, Artificial intelligence, Education, AIED
Categories: H.3.1, H.3.2, H.3.3, H.3.7, H.5.1
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1 Introduction

Adaptivity is one of the innate abilities of human beings, which allows them to analyze the details of each situation in order to act in the correct way. This capacity develops to different degrees from one person to another, depending on the experiences, habits and perception of each one. It should be noted that this ability is not limited to humans

alone, but is found in other creatures to varying degrees. For example, when a predator detects an animal, selects it as prey, changes its position to pursue it and then pounces on it as a form of appropriate response deployment. This process of detection, selection, modification and deployment is an adaptation to a particular situation. As long as the degree of adaptivity grows, as long as we approach the creativity that is a desirable human characteristic [Spector, 2016]. Related to human learning, especially in the field of education, adaptivity indicates the ability to design a student model representing these beliefs, preferences and needs based on a system that aims to provide, for example, learning materials, learning sequences, feedback, tutoring, interface and presentation adapted to this model [Chou et al., 2015].

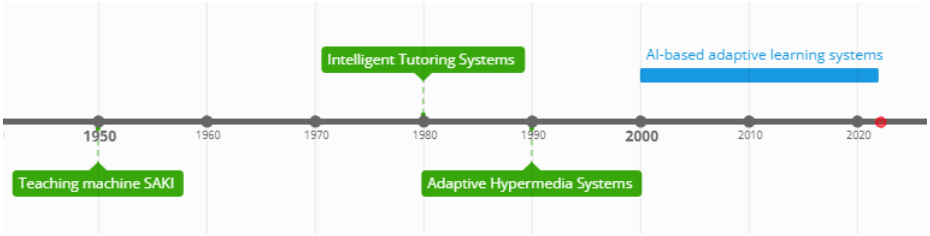

Figure 1: The timeline of adaptive learning development

Our current study focuses on artificial intelligence (AI)-based adaptation in the field of education. This term emerged with the evolution of teaching-learning platforms and applications. The self-adaptive keyboard instructor (SAKI), which was initially used in the 1950s, is where this first appeared [Pask, 1982]. New advancements in the subject of adaptive learning have come about over time as technology has advanced and changed, including intelligent tutoring systems in the 1980s and adaptable hypermedia in the 1990s [Psotka et al., 1988, Wilson and Scott, 2017]. In the 2000s, as illustrated in Figure 1, a new approach to education known as AI-based adaptive learning emerged with the development of artificial intelligence technologies [Kara and Sevim, 2013], representing the one of the reasons for examining the progress of AI-based adaptive learning since that time. This approach involves using highly powerful artificial intelligence algorithms to create customized content and pedagogical paths based on the needs, responses, learning styles, preferences, and other factors [El-Sabagh and Hassan, 2021, Zniber, 2005]. In other words, adaptive learning is an educational approach that customizes the learning experience for each student based on a variety of variables, including cognitive, affective, and demographic background. This approach can be incorporated into conventional classroom as well as online learning environments using AI and machine learning algorithms [Forsyth et al., 2016]. In addition, adaptive learning environments and adaptive learning platforms are two related concepts that refer to learning spaces, which use these algorithms to successfully apply this strategy while using a range of multimedia resources, interactive activities and assessment tools [Afin et al., 2019] [Liu, 2022].

According to this research [Sun et al., 2005], adaptability in education is becoming more and more important in order to boost the effectiveness and efficiency of the teaching and learning process. In 2010, [Bian et al., 2010] noted that adaptive learning has developed into a trend in modern distant education as well as a significant topic of

research. According to the research conducted by [Peng et al., 2019], adaptive learning integration is growing due to smart devices and smart technologies, which is a trend. Recently, as shown by the study of [Ezzaim et al., 2022], one of the trends in educational scientific research has been AI-based adaptive learning. This bibliometric investigation revealed that this type of systems is one of the most frequently addressed topics, accounting for 33% of the research on AI applications in education as shown in the following graph [Ezzaim et al., 2022].

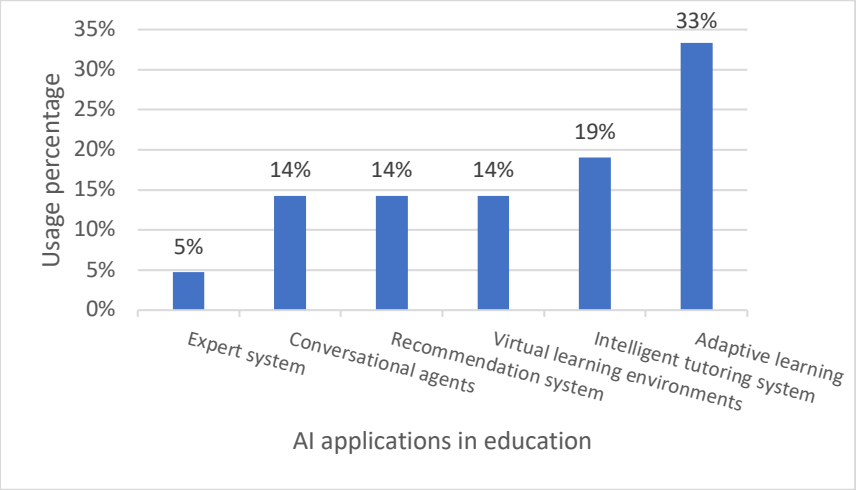

Figure 2: Artificial intelligence application in education

In this respect, we decided to conduct a comprehensive review of the literature related to AI based adaptive learning, in order to help both the scientific and educational communities in understanding the adaptive learning approach, the systems employed, and the AI techniques utilized. This review examines the current status, challenges, limitations and future visions.

To accomplish these purposes, a systematic mapping analysis was used. In general, this methodical choice allowed us [Petersen et al., 2008]:

- To categorize and analyse the topics covered in the literature.
- To have an overall view of a field regarding the current state, gaps and future directions of research

In particular, this choice enabled us:

- To map scientific papers related to adaptive learning published between 2000 and 2022.
- To review the progress of AI based adaptive learning since 2000.
- To determine the AI technologies used, their educational applications and advantages according to empirical research.

Our paper is structured as follows. The second section aims to present the key concepts and fundamentals of adaptive learning in its entirety. The third section explains the research approach used, including the stages of the systematic mapping process. The fourth section highlights the research results. This is followed by the fifth section, which answer the research questions, followed by a conclusion of the paper.

2 Frame of reference

2.1 Adaptive learning definitions

According to the interpretation stated by [Mayer, 2010] “Learning is the relatively permanent change in a person’s knowledge or behavior due to experience”. As mentioned in the introduction, "Adaptivity" is one of human beings' intrinsic skills, allowing them to study the intricacies of each circumstance in order to act appropriately [Spector, 2016]. When we combine these two terms, we get adaptive learning, which can be defined based on the previous two definitions as improving a person's knowledge while studying their complexities in order to provide the best possible experience. In [Kerr, 2016] adaptive learning is a method of automatically distributing online learning material based on the learner's engagement with previous content. Adaptive learning, according to the US Department of Education's Office of Instructional Technology [US Department of Education, 2010], is more than simply a method; it is educational technology in three different forms: The first is individualization, in which all students have the same learning objectives but can progress through the content at various rates. The second form is differentiation, in which all students' learning objectives are the same, but the teaching style or approach differs based on each student's preferences or what research has discovered works best for students like them. Personalization is the third form, in which the learning objectives and content, as well as the technique and pace, may all be customized.

On the other hand, researchers see adaptive learning as an educational approach, which uses several technologies to create a personalized learning experience for students depending on their behavior, interaction, aptitude, learning styles and performance [Forsyth et al., 2016] by implementing the “one-size fits all” method [Partners, 2013].

Based on this review, the notion of adaptive learning can be defined as a technology-based approach represented by educational systems and platforms that try to tailor pedagogical content, presentation styles, or learning paths to individual profiles, such as cognitive state, affective status, and knowledge level. We should also mention that, as shown in fig 1, the systems or environments designed to implement this approach have undergone a series of developments, innovations, and improvements [Samia, 2014] linked to technological evolution, either in their forms or in their objectives and adaptive capacities provided [Ball, 2012], making a standardized definition difficult to adopt.

To begin, there are intelligent tutoring systems (ITSs), which are a specific type of adaptive system that have been developed over the last four decades by researchers from education, psychology, and artificial intelligence (AI). These systems are designed to stimulate the teacher's role in teaching and are based on four models: the Expert Model, the Pedagogic Model, the Learner Model, and the Communication Model [Phobun et al. 2010, Al-Bastami et al., 2017, Chunyu, 2017]. Second, Adaptive

Hypermedias (AHs) which refers to the relationships between the elements of any type of media and offers in particular an adaptability of navigation and presentation [Chunyu, 2017]. Third, the use of web-based technologies in conjunction with the capabilities of AHs and ITS to offer the right content at the right time, to determine current levels of understanding, and to track real-time interactions with the system for students who are physically separated from their teachers [Esichaikul et al., 2011]. Fourth, there are AI-based adaptive learning systems, which are the focus of our study and are based on machine learning approach. These systems will be described in detail in the following sections [Schneider et al., 2003, Beldagli et al., 2010, Chunyu, 2017].

2.2 AI-based adaptive learning systems

Artificial intelligence (AI) is a branch of computer science that aims to integrate intelligent behavior of humans or animals into computer systems in order to handle complicated problems with little or no human intervention [Hamet and Tremblay, 2017, Nilsson, 2009, Whitby, 2008]. Over the past three decades, artificial intelligence has established its position in the field of education through its contribution to the development of tools to support and understand the teaching-learning process [Bengio et al., 2015, Luckin et al., 2016]. The continuous improvement of these AI-based tools has allowed for the development of more efficient learning systems and platforms, providing learners with high quality and specific educational content, adapted to their individual needs and preferences [Kurilovas et al., 2015].

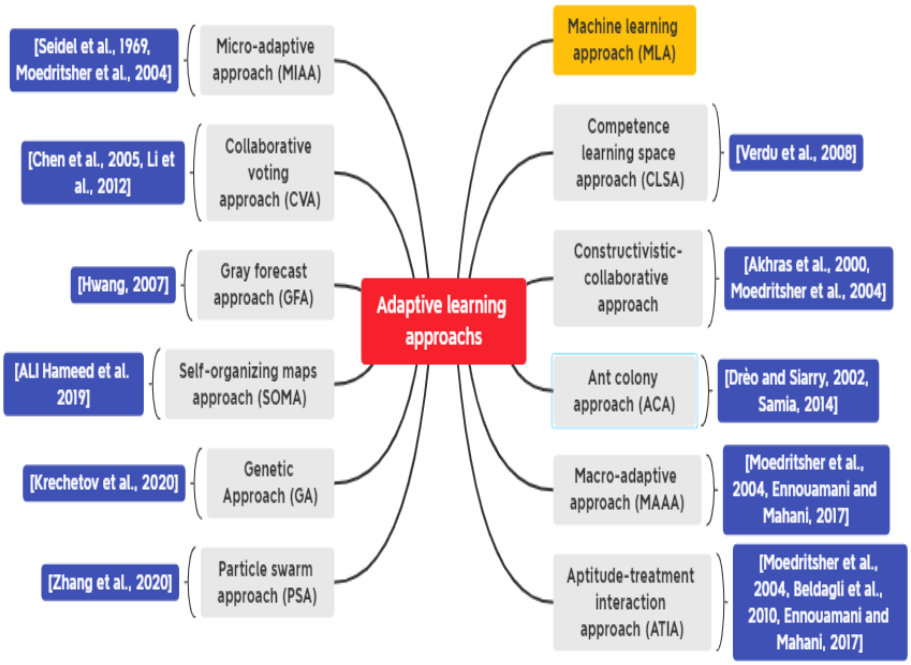

Figure 3: Adaptive learning approaches

As shown in figure 3, there are several adaptive learning approaches, although these AI-based learning systems are built in most cases on one of these approaches supplemented by the machine learning approach, which is a subset of artificial intelligence [Samuel, 1959] that attempts to solve data problems in a variety of disciplines using a range of algorithms [Mahesh, 2019]. Machine learning is at the heart of many adaptive learning systems, which provide better support to the learner, suggest potentially useful material, adapt the instructions to the learner's learning strategies, preferences, and difficulty, generate unique learning paths and provide live feedback [Syed et al., 2017, Hasanov et al., 2019, Pliakos et al., 2019]. In other words, intelligent tutoring systems, adaptive learning systems, and recommender systems are all included in AI-based learning environments [Kabudi et al., 2021]. However, as mentioned in [Kabudi et al., 2021] AI, learning analytics and educational data mining are examples of techniques that have accelerated the development of these systems to provide an enhanced learning experience, time flexibility, timely feedback, flexibility in managing student learning experiences and faster student progression [Pliakos et al., 2019, Chou et al., 2018, Moreno-Guerrero et al., 2020].

AI-based adaptive learning is not usually a whole system or environment; it may also be a module integrated into a Learning management system (LMS) to improve its functionality by allowing learners to navigate and sequence content more easily to meet their needs. These modules also provide the option of correcting answers with justifications to help students understand how and why things work, as well as taking advantage of the vast number of knowledge resources available online to further their understanding of the subject and using multilingual learning services to present them in the student's preferred language [Suleiman, 2018, Surve, 2020].

Some of the most commonly used AI techniques, as identified by the Tumaini Kabudi et al. study [Kabudi et al., 2021], include Bayesian networks, neural networks, decision trees, genetic algorithms, K-nearest neighbour, Support vector machines (SVMs) and Bayesian knowledge tracing (BKT).

At the end of this part, we note that in recent year AI has played a key role in solving learning and teaching difficulties such as increasing students' learning experiences and outcomes, developing more personalized pedagogical frameworks, and addressing poor motivation and engagement [Kabudi, 2021]. However, few actual applications have been uncovered, indicating that most AI-based adaptive learning systems have been discussed in the literature but not implemented in real-world situations [Imhof et al., 2020].

3 Research Methodology

In order to put this study into practice, the systematic mapping method was adopted. Through the study and classification of scientific articles connected to the intended research field, this method helps both to gain an understanding of a research area and to answer research questions aimed at detecting research trends [Petersen et al., 2015]. In other words, as compared to bibliometric analysis, which also provides ways for commenting on and evaluating scientific research through the intensity of output in a certain subject [Marcon, 2015], this content-based form of analysis, is more powerful in terms of mapping a broad field of research [Babak et al., 2015].

Many researches, particularly those in the field of education, have used the systematic mapping method, including:

- To obtain insight into AI-enabled adaptive learning systems, this study [Kabudi et al., 2021] performed a systematic mapping of the literature published between 2014 and 2020.
- This study intends to present empirical research on the applications of gamification in education using systematic mapping approaches [Dicheva et al., 2015].
- Using this approach, this study [Babak et al., 2015] aims to map the current research and gaps in the field of ICT (Information and communication technology).
- As indicated in this work [Barbosa et al., 2013], which attempts to give a thorough evaluation of primary studies on software ecosystems, the Systematic Mapping approach is also employed in other fields.

In our study, systematic mapping is the most effective method for analyzing the attributes of scientific articles published in the field of AI for adaptive learning between 2000 and 2022. The purpose of this analysis is to respond to the research questions presented in the introduction. To accomplish this, three main processes were taken: first, define the study questions, which in turn identify the overall purpose; second, collect relevant articles using a keyword search, followed by criterion selection; and third, data extraction and mapping.

As previously stated, the designation of objectives is the first step in any systematic literature mapping. In this case, four research topics relevant to AI-enabled adaptive learning have been proposed:

- Q1: What are the primary research goals of AI adaptive learning studies?
- Q2: In what ways has AI-based adaptive learning addressed research issues and concerns?
- Q3: What are the popular AI algorithms used to design interventions?
- Q4: What impact will present research have on future AI-based adaptive learning practices?

3.1 Search strategies and Data sources

Nowadays, online scientific publication is occurring at a rapid pace, making it nearly impossible to perform thorough research even with clearly established criteria. A search strategy is implemented when the objectives are identified and in order to answer the research questions, beginning with the selection of keywords and the Boolean operators utilized. We concentrated our search on three key terms: "adaptive learning", "education" and "artificial intelligence" as well as synonyms like personalized learning, adaptive learning environment, adaptive learning system, and AI. These terms were combined using the Boolean operators OR and AND to get the final search string (See Table 1).

This study was carefully conducted in five databases (i.e. Sciencedirect, Scopus, ERIC, IEEE Xplore, Mendeley), because this databases contain recent and relevant papers as well as a variety of scientific journals linked to AI and education (e.g. Neurocomputing, Computers and Education, Computers in Human Behavior, Computers & Education, International Journal of Educational Technology in Higher

Education etc.). In order to expand our research area and increase the number of research analyzed, we also used the Google Scholar search engine.

Search string
adaptive learning AND artificial intelligence
adaptive learning AND artificial intelligence AND Education
adaptive learning AND AI AND Education
(personalized learning OR adaptive learning) AND (environment OR system) AND (artificial intelligence OR AI)

Table 1: Keywords used in the search string

3.2 Inclusion/exclusion criteria and results

Multiple rounds of searches were conducted using different selection criteria to determine what should be included and excluded in order to find the answers to the research questions that were given. Since our study aims to highlight the state of the literature in the field of AI-based adaptive learning, the first phase was based on the search strings generated as well as the date criterion, which allowed us to select studies published between 2000 and 2022 as well as those directly related to adaptive learning. After the aforementioned initial phase, approximately a total of 740 articles were recovered.

To reduce the number of articles, a second phase of selection is implemented which aims to remove duplicates then apply the following exclusion criteria:

- Non-English articles.
- Opinion Investigations or presentations articles.
- Reports.
- Dissertations.
- If the title does not include the terms adaptive learning, personalized learning or artificial intelligence.

This phase produced around 170 peer-reviewed articles published in academic journals. Thirdly, abstract and keyword screen applying the following inclusion criteria yielded nearly 120 articles:

- Research must focus on AI-based adaptive learning.
- Research must focus on educational settings.

After thorough selections and full-text analyses, a total of 93 articles reporting relevant qualitative or quantitative data as well as having examined the effects of AI-based adaptive learning were selected for full analyses.

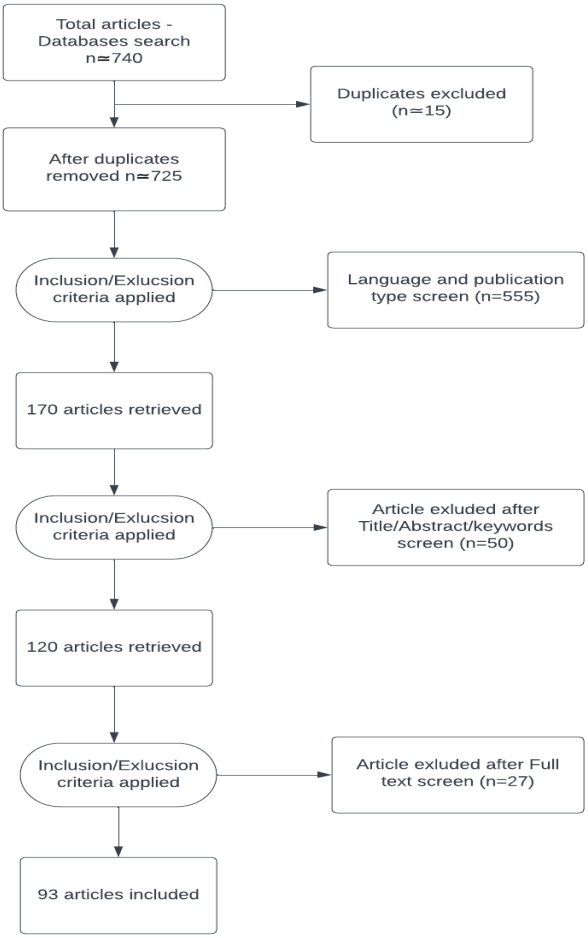

Figure 4: Flowchart for the systematic mapping process

3.3 Data extracted

Following a thorough study of the chosen articles using the suggested criteria, various data were retrieved. By using the Zotero program, we were able to retrieve the title, authors, year of publication and reference type of each article. The name of the journal, the abstract and the keywords of the publications were also extracted. After analysing the full text, we extracted the type of intervention used in each research, the solution and the AI algorithms employed, the factors taken into consideration and the objective addressed.

4 Results overview

The purpose of this section is to synthesize and describe the results from the research that served as the basis for the generation of our sample data utilizing descriptive static analysis [Sugiyono, 2014]. This analysis attempts to provide the article landscape, AI techniques, background, systems employed, and research trends related to adaptive learning.

4.1 The landscape of research publications on adaptive learning

The objective of this part is to present the frequency of publications on AI-based adaptive learning in terms of years, continents and journals.

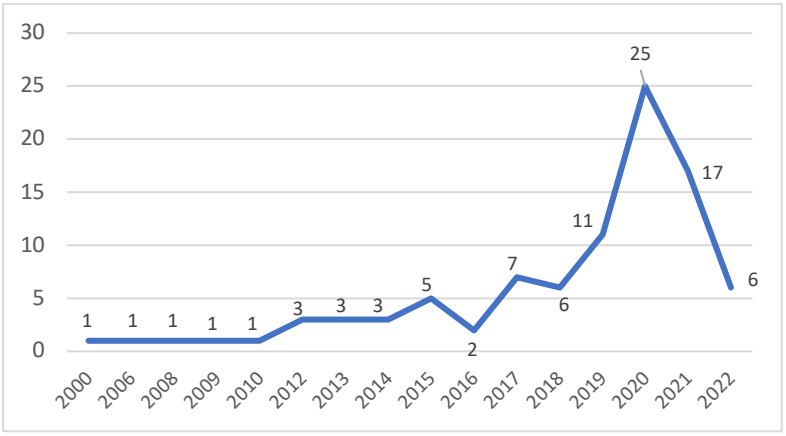

Figure 5: Number of publications per year related to AI-based adaptive learning

The graph above depicts the number and annual distribution of our sample's 93 studies. As shown, the number of publications in the field of AI-enabled adaptive learning has increased from 2000 to 2022. Particularly, in the years after the COVID-19 pandemic. 2020 had the most publications (25 articles), representing 27% of the total. 2021 came in second with 17 publications, followed by 2019 with (n = 11), 2017, (n = 7), 2018, and 2022 with 6 publications, followed by 2015 with (n = 5), 2014, 2013 and 2012 with (n = 3), as well as 2000, 2006, 2008, 2009, and 2010 with one publication each.

Numerous countries throughout the world conduct research on AI-based adaptive learning. Regarding the highly prolific contients, we note that, as shown in Fig. 6, the Asian region (53 publications) has a wide concentration of publications in this area, specifically China, with 16 articles. Then comes Europe with 30 publications. Six of them were realized in the United Kingdom. Interestingly to note that even if the American continent comes in third (17 publications), the USA is rated second when comparing the frequency of publishing in terms of countries, with 11 contributions. Furthermore, with 8 publications, Africa is the fourth-most prolific continent, lead by Morocco's 4 articles. Australia, located on the continent of Oceania, is one of the additional countries that contributed to the expanding body of research on AI-based adaptive learning with three articles.

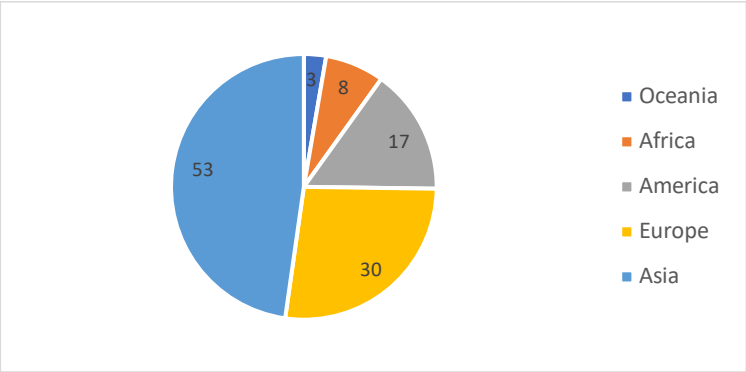

Figure 6: Number of publication per continent related to AI-based adaptive learning

After identifying the continent (Asia), country (China) and year (2020) with the highest frequency of publication, we can now address the frequency of journals as presented in the table 2 below.

Journal	**Number of studies**	**Percent**
Computers & Education	15	17.64
Education and Information Technologies	6	7.05
Computers and Education: Artificial Intelligence	5	5.88
Computers in Human Behavior	4	4.70
International Journal of Educational Technology in Higher Education	3	3.52
International Journal of Emerging Technologies in Learning	2	2.35
Applied Psychological Measurement	2	2.35
Computer Applications in Engineering Education	2	2.35
Others	46	54.11

Table 2: Research journals with the highest publication rates in adaptive learning

According to our sample, the number of articles on AI-based adaptive learning has increased over the past twenty years, with Computers & Education journal publishing the most number of 15 articles. This journal, which is listed in various abstract and citation databases (eg. Scopus) seeks to advance knowledge and comprehension of the ways that digital technology might enhance education [ScienceDirect C&E, 2023]. As indicated in Table 2, Education and Information Technologies journal came in second with 6 papers, followed by Computers and Education: Artificial Intelligence with 5 articles, Computers in Human Behavior with 4 articles etc. It should be noted that Computers and Education: Artificial Intelligence is a sister journal of Computers and Education with the goal of presenting pedagogical breakthroughs in connection with applications of AI in education on a global platform [ScienceDirect CAEAI, 2013].

4.2 Educational contexts

In this part, we will present the educational contexts, namely the levels and subjects mentioned in the reviewed research.

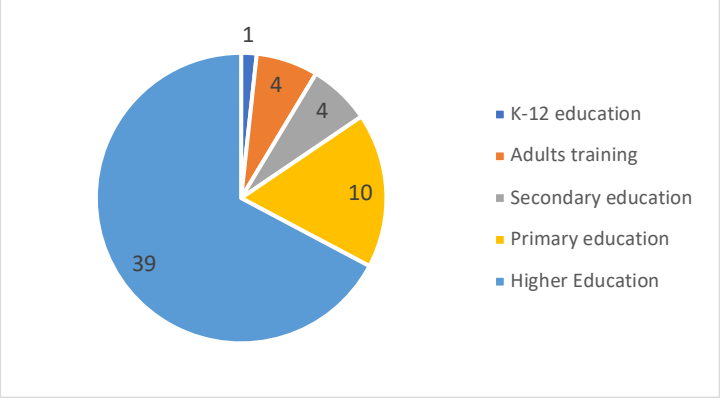

Figure 7: Educational levels composing our samples

In terms of educational levels as shown in fig.7, 67 percent of research focuses on higher education (n = 39), while 17 percent (n = 10) focuses on primary education, 14 percent split equally between secondary education (n = 4) and adult training (n = 4), and 2 percent (n = 1) is represented by K-12 education.

AI-based adaptive learning is investigated in a variety of fields, including informatics, sciences, languages, healthcare, business, soft skills etc. Computer science, namely programming and data structures, is the subject of the majority of research (n = 19), which is then followed by mathematics (n = 8), languages, and communications (n = 6), physics, chemistry (n = 3), and more (See Table 3). Not to mention, research that focuses on adapting the learning of various concepts comes in third with a rate of 12% (n = 6).

Disciplinary area	**Number of studies**	**Percent**
Computer science	19	38.77
Mathematics	8	16.32
Multiple concepts	6	12.24
Languages and communication	6	12.24
Physics and chemistry	3	6.12
Nursing, medicine and pharmacy	3	6.12
Economy and Business	1	2.04
Biology	1	2.04
Learning skills	1	2.04
Scientific subjects	1	2.04

Table 3: Disciplinary areas addressed in adaptive learning research

We can conclude that Adaptive learning based on AI is more common in higher education, particularly computer science education. There are numerous reasons why this might be. In the first place, the demographic, affective, and cognitive traits of the students in these cycles, such as their ages, their propensity for using digital learning environments, their autonomy, their intrinsic motivation, etc. The second is that universities should be able to invest more money and resources in building out their technological infrastructure. As for computer science, this discipline is closely tied to technology, which facilitates its teaching using digital tools. However, because computer science curricula are complex and constantly evolving, access to up-to-date technological resources is necessary. In addition, students studying computer science typically feel more at ease using digital tools and online resources.

4.3 AI-based adaptive learning interventions

Based on the interventions used to apply the adaptive learning technique using AI, as accomplished in [Kabudi et al., 2021], our research sample has been divided and refined into 10 groups (System, Model, Approach, Game, Framework, etc. (See fig. 8)), through an iterative process of coding and discussion among the authors.

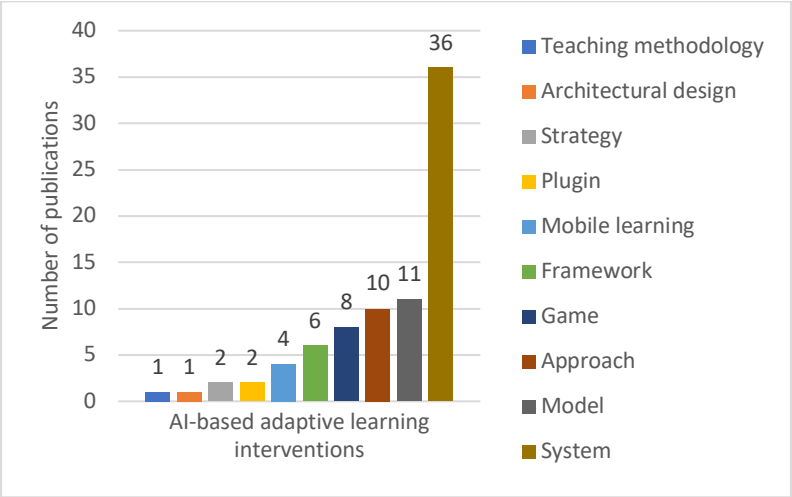

Figure 8: Types of AI-based adaptive learning interventions

In terms of the types of AI-based learning interventions, we can confirm that researchers are very interested in the design, development, and testing of adaptive learning systems and platforms, as shown in Fig. 8, of which 36 publications are in this direction (44%). On the other side, 11 highlight AI models supporting adaptive learning (14%). To put it simply, a model is generally a description of a pattern that aids in visualizing something that cannot be seen directly [Kühne, 2005]. Particularly, an AI model is a collection of complex algorithms that analyzes a variety of inputs to recognize specific patterns. This analogy enables one to predict, categorize, or draw a conclusion [Curtom et al., 2022]. 10 articles address the various theories, perspectives and methodologies used to approach the problem of adaptability in the learning process

(12%), while 8 are interested in adaptive serious games and the ludic dimension in the service of learning adaptation (10%). Wide-ranging advantages of this intervention refers to games that are used in a range of educational settings to improve learning by helping students to acquire knowledge and skills [Kaimara et al., 2020]. Following that, 6 research focuses on developing a Framework that allows for the adaptation of the educational process which represents 7% of the total, 4 studies on learning using mobile devices (smart phone, tablet) (5%), and 4 divided between the learning strategies and the plugin integrated into the LMS. The plugins suggested as solutions in our sample are a combination of libraries and algorithms that empower a learning management system (LMS) with adaptive capabilities. In order to better understand other ideas, let us define a framework as a structure that solves issues by inserting a general design that offers the required functionality [Stamer et al., 2016]. In our context, it is utilized to make sane decisions about adaptive learning design and to create a roadmap outlining actions, models, and artificial intelligence technologies that are beneficial for achieving a highly successful adaptive learning result [Bower, 2016]. Learning strategies describe a group of procedures, tools and plans that can make it easier to gather, store and implement data in the interest of adaptive learning [Dansereau, 1985]. Finally, we discover that only one contribution for each, architectural design and teaching techniques are the AI-based adaptive learning interventions that receive the least attention in this literature.

4.4 AI-based adaptive learning technology applications

AI-based technology offers a wide range of potential for education, including the ability to personalize the learning experience for each student. Through our sample, we were able to extract several types of AI-based applications used in the service of learning adaptation. As shown in the following figure, 38 applications (48%) are interested in web-based platforms, seven are related to recommendation systems (9%), 12 are divided between intelligent tutoring systems and educational games (15%), and 4 contributions are interested in prediction systems (5%). For the remaining applications, we find, six publications related to Mobile applications and E-learning plugins representing 8% for each, whereas chatbots, offline learning environments and expert systems each was mentioned in two searches. As for the least used systems, the following are found: educational hypermedias, semantic bliki systems, intelligent control systems, hybrid environments, dashboard systems and adaptive instructional systems.

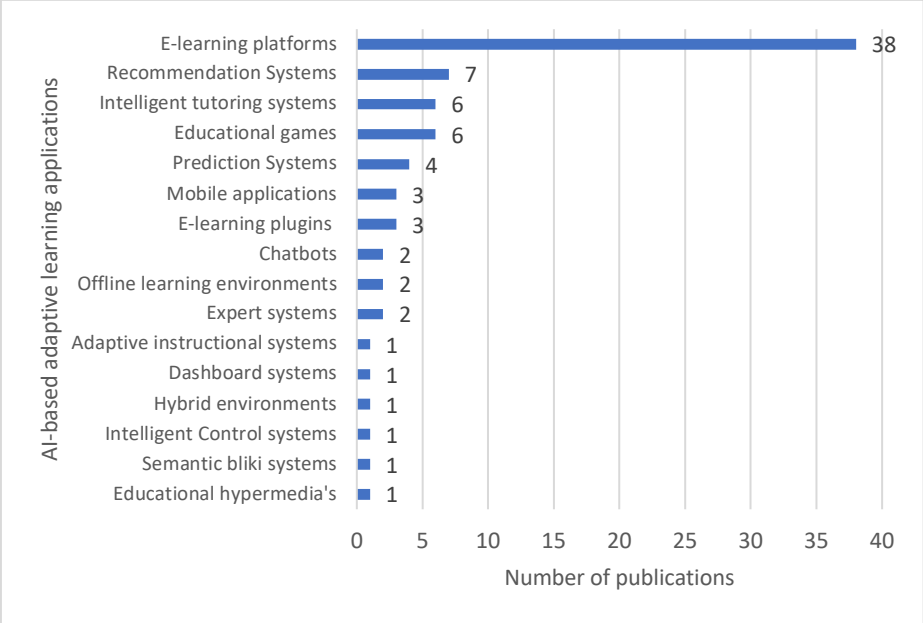

Figure 9: Types of AI-based adaptive learning technology applications

Due to their immense potential in terms of convenience, flexibility, presentation of a wide range of course materials, online adaptive learning systems came in first. From the perspective of teachers who conducted a study in Taiwan with 76 students, these platforms improve learning, identify barriers to learning, and provide useful feedback [Liu, 2022]. Another study that involved three groups of college freshman revealed that the adoption of adaptive web-based learning systems has a favorable impact on students' motivation to learn [Lo et al., 2012]. By mapping optimal individualized learning paths for students in online courses, a web-based adaptive learning platform also helped instructors track their students' performance in real time and monitor their recent progress based on the analytics generated [Krechetov et al., 2020].

The recommendation systems that come in second place are based on a variety of factors, such as the learner's past behavior, preferences, and demographic data (content-based filtering) or the past behavior of other learners and their interactions (collaborative filtering). These systems aim to improve the learning experience by offering personalized recommendations, increase learning efficiency by analyzing a large amount of information, providing real-time recommendations; optimizing navigation time and helping the learner find the most appropriate learning content [Urdaneta-Ponte et al., 2021]. A recommendation system called X5Learn optimizes learning paths based on the interests of the student and offers a clear interface for choosing educational materials. As said in this study [Perez-Ortiz et al., 2021], the usability applications of these systems have demonstrated that they helped students better engage with the content by facilitating their ability to navigate it. A study on the implementation and evaluation of a recommendation-based hybrid adaptive learning system showed that recommending learning content appropriate to the needs of each

learner contributes to improving the learning effects. In particular, this research investigated how to use content-based and collaborative-filtering based hybrid recommendation technology in an adaptive learning system through a field experiment with 30 selected students from the undergraduate computer science program [Xuekong et al., 2015].

The third major system in our study sample is the intelligent tutoring systems, which stand for an effective self-learning tool that makes choices depending on the learner's affective and cognitive state, as well as provide a customized learning environment by tailoring the learning process and content to each unique learner [Zatarain et al., 2020] [Chrysafiadi et al., 2021]. This astounding usage rate is a result of the numerous benefits that these kinds of systems provide, including customized lessons, quick responses, increased engagement, and improved learning outcomes, as demonstrated by the studies that follow. This study [Crockett et al., 2017] examines the effects of OSCAR, an intelligent tutoring system that converses in natural language to identify the learner's preferred learning style and utilize it to dynamically tailor tutoring sessions. Another study suggested a fresh method for developing intelligent tutoring systems that relies on serious games and adaptable processes. With the use of these innovative summative assessment techniques, teachers may now motivate and inspire their students to learn [Beyyoudh et al., 2019]. This method leads us to the fourth system type, adaptive educational games, which is comparable to the latter in term of study percentage. These AI-based solutions, which primarily aim to adjust a portion or all of the learning process, also boost learner motivation and engagement, enhance social and collaborative abilities, and incorporate multi-sensory learning. An adaptive gamified learning system that combines classification, gamification, and adaptation approaches was created to improve the efficacy of online learning. A data structure course was taught to 73 students using three different teaching approaches to evaluate this solution: classical, gamification, and adaptive gamification. The findings indicated that, when compared to alternative approaches, the adaptive gamification method improved student engagement and academic achievement [Daghestani et al., 2020]. Additionally, other crucial applications that are significantly influential on the learning process include:

- Prediction systems that analyze learner data to predict several key elements of the adaptation mechanism (performance, learning style etc.) [Kolekar et al., 2017].
- Mobile applications that provide easy access to learning materials, convenience and flexibility so that students can learn at their own pace and according to their own interests [Louhab et al., 2018].
- Plug-ins that adds new, non-existent adaptation functionality to an LMS [Zabolotskikh et al., 2021].
- Chatbots, which are a solution characterized by availability, immediate feedback, efficient information dissemination etc. [Janati et al., 2020]
- Dashboard that allows teachers and administrators to view and analyze instructional data in real time to improve their decisions and allow them to adapt their teaching [Han et al., 2021].
- Educational hypermedia that provides a high level of information organization enables students to investigate complex concepts etc. [Akbulut et al., 2012]

4.5 AI techniques and algorithm typologies

Based on the mapping of collected studies we revealed a wide number of AI algorithms used to deal with problems related to learning adaptation. In this regard, we have chosen to classify these algorithms into four groups, those related to symbolic AI, machine learning, neural networks, Natural language processing (NLP) and Deep learning. The figure below shows the frequency of these AI algorithm typologies used in the collected studies.

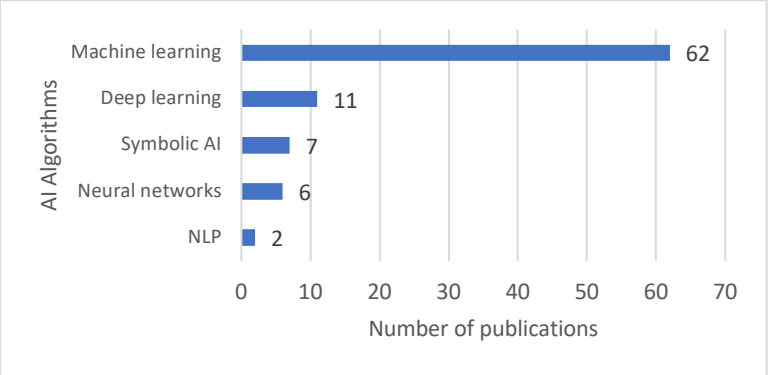

Figure 10: Typologies of AI Algorithms used in Extracted Studies

The most common category was Machine learning algorithms (e.g. Decision Tree algorithm, Support Vector Machine algorithm, K-means clustering algorithm), which were referenced in 62 of the identified studies. Deep learning algorithms (e.g. Convolutional Neural Networks, multi-layer feed-forward neural network) are the second most frequently stated types (n = 11). Seven studies used algorithms falling into the category of symbolic AI (e.g. Rule-based algorithm, Fuzzy rules algorithm), followed by six adopted neural networks algorithms (e.g. Radial Basis Function Neural Networks, Gravitational Search based Back Propagation Neural Network). The remaining ones are classified as NLP (n = 2).

In a 2020 study, the J48 decision tree algorithm was utilized to create a model for categorizing learners according to their learning styles, which was then applied in an adaptive virtual learning environment. This methodology made it feasible to accurately identify learner preferences and nimbly tailor the user interface and course material [Renato et al., 2020]. To calculate the similarity of the user target in a hybrid recommender system, the K-means algorithm was used to deal with the clustering of users based on their collected information [Xuekong et al., 2015]. In an adaptive mobile learning environment, researchers used ensemble classification with the Support Vector Machine algorithm to automatically detect learning style. Learner outcomes have improved as a result of this environment where learning content is altered based on learner preferences [Troussas et al., 2020].

In this research [Standen et al., 2020], a Convolutional Neural Network (CNN) model for inferring emotions from face images was implemented with the aim of identifying facial expressions and estimating gazes in adaptive learning system which will then allow to classify learners with intellectual disabilities. In order to subtly

identify students' cognitive styles and use them to suggest learning content adaptively, a multilayer feedforward neural network (MLFF) was used in this research [Lo et al., 2012]. This multilayer network has the capacity to handle imprecise or incompletely understood data and can be quickly updated with new parameters.

A research that primarily focuses on developing a reinforcement model for an adaptive learning environment based on learners' cognitive skills has used a fuzzy-based rule system to formulate the action sequence from the opinion survey and then map the cognitive skills with the learning object (LO), which will allow for learner-to-learner variation in learning content [Balasubramanian et al., 2018]. Rule-based reasoning is a technique that other researchers have used to teach Chinese [ù et al., 2020]. The NAO robot was able to understand the audience's vocal answers through the use of selection reasoning (IF-Subsequently-ELSE), which then allowed it to extract the audience's keywords. Through this novel learning experience, students' comprehension and word retention have improved, and the process has gained a fun element that engages and inspires them.

In order to categorize students with learning difficulties and predict their propensity to not graduate on time, this research [Lagman et al., 2020] used a Basic Neural Network Algorithm to create remediation and tutoring strategies that were suited to learners' preferences.

To build a chatbot that can converse with students and recommend e-learning materials that are tailored to their need, a Natural Language Processing technique is introduced to extract keywords and then use them to index multimedia. This strategy is an effective way to categorize multimedia information using keywords [Janati et al., 2020].

It is necessary to present a different typology that only focuses on machine learning algorithms, which are the most, used in adaptive learning solutions, particularly at the level of prediction and classification, as demonstrated in fig. 9.

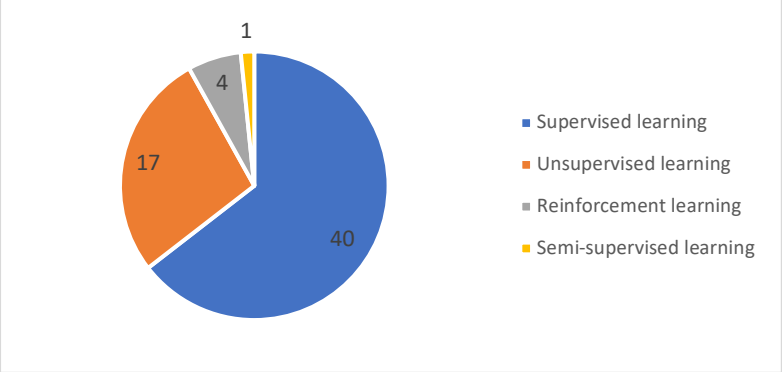

Figure 11: Typologies of Machine learning Algorithms used in Extracted Studies

The frequency of papers using or mentioning machine learning algorithms is represented in the graph above. The most commonly referenced algorithms in this research were supervised learning algorithms. This class of ML algorithms, which primarily enable the solution of classification (e.g. Learning behavior-based

classification [Abhirami, 2021]) and prediction (e.g. Learning style prediction [Crockett et al., 2017]) issues, have been created, discussed, and applied in a total of 40 articles. Unsupervised learning were the next most commonly listed ML algorithms type (17 studies). The main goal of this type is to reduce the number of variables in a dataset and cluster data into groups or segments (e.g. cluster the learning behaviors data into learning style categories [Kolekar et al., 2017]). The recommendation of material is another example of how these algorithms are used [Xuekong et al., 2015] [Nabizadeh et al., 2020]. This mapping also identifies the reinforcement learning algorithms that have been adopted in four studies. In turn, these algorithms enable the creation of intelligent educational games [Dobrovsky et al., 2017] [Sayed et al., 2022], the construction of recommendation systems based on the principle of rewarding desired behavior [Bennane, 2013] [Tan et al., 2020] [Spain et al., 2022], etc. Semi-supervised algorithms, which are created for classification issues with constrained amounts of labeled data [Dunham et al., 2019], are the final category represented by a single search.

4.6 Research objectives

According to the findings in Fig. 12, 25 research (26%) seek to improve learning performance, which is the capacity of a learner to apply knowledge to activities that are relevant to their daily lives [Hwang et al., 2020]. Increasing the learners' motivation rate, which is typically measured by their engagement, is the second target that is frequently addressed (n = 21; 22%) [Standen et al., 2020] [Kickmeier-Rust et al., 2019]. The third goal of the gathered studies is to improve learning efficiency (n = 11) and achievement (n = 11), which relate to, respectively, how effectively and efficiently a learner acquires knowledge [Tan et al., 2020] and the benchmark to know the success of learner in the learning process [Tseng et al., 2008] [Younes, 2021]. The objective of 7 studies among the total, deals with how to customize the course content or the types of resources to meet the different demands of the learners [Gomede et al., 2021]. Improvement of Students' satisfaction [Hammami et al., 2015] and learning ability (e.g. Reduce the cognitive load [Demircioglu Diren et al., 2022]) were also identified in this mapping, each with four studies, followed by, Decisions making (n = 4), which leads to the improvement of the quality of teaching [Villegas-Ch et al., 2021]. The remaining identified objectives are presented in the graph below.

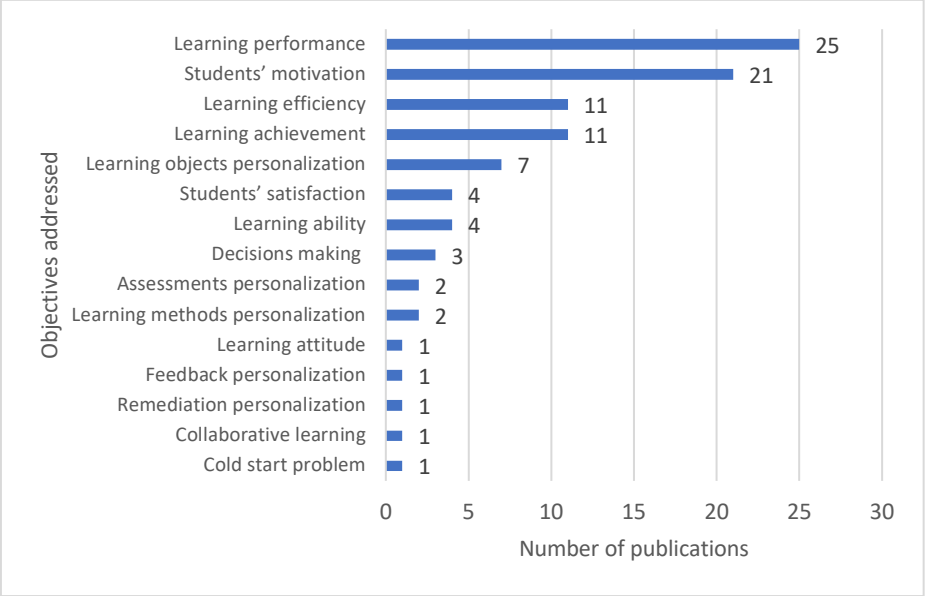

Figure 12: Objectives addressed in the extracted studies

4.7 Adaptive factors

Through this part, we seek to outline the various factors considered throughout the learning adaptation process. These factors are typically connected to the learner model, which describes learner qualities, knowledge and skill, behavior, preferences, and individual differences that are utilized to customize the material [Martin et al., 2020].

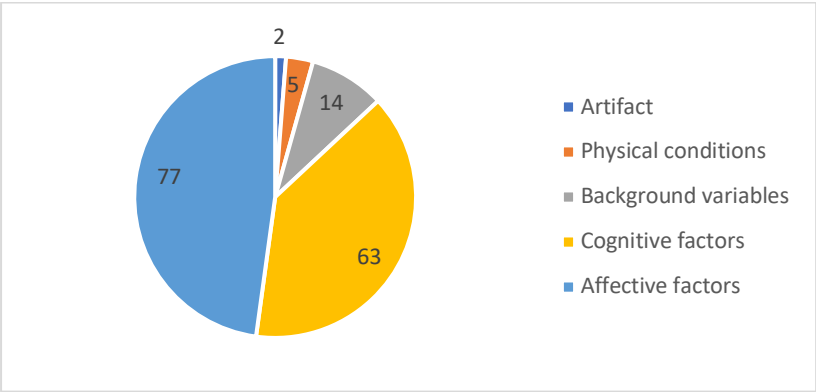

Figure 13: Factors considered in adaptation

The most common factors are depicted in the figure above. The highest percentage (48%) belonged to Affective factors (77 studies), divided as follows: 32% for learning styles, 13% for preferences, 12% learning behavior and 5% for the degree of learner

motivation. The rest, which represents 38%, is divided between the following parameters: Personality traits, Experience, Emotions, Persistence, Time management, Student's Feedback, interest, clicks, viewing time, imperfect help-seeking behaviors, degree willingness to learn, degree patience, degree of concentration etc.

The second most frequent factor with 63 publication belonged to cognitive dimension (39%), which refers to the learner's mental abilities. These abilities relate to the learner's domain knowledge with a percentage of 29% of the total, learners' performance for 13%, responses provided and academic success for 20%, 8% for study level, 6% for learners' solutions, 5% for taken time and 3% for learning progress. For the remaining 16%, they each represent the following factors: learner's proficiency, learning deficits, students' vulnerability and students' needs.

Other factors are taken into consideration, such as: personal data represented (n = 14; 9%), physical conditions (n = 5; 3%) and artifact (digital and physical properties) with a small percentage of (n = 2; 1%).

5 Discussion of findings

In this section, we will interpret and discuss the results obtained while answering the research questions. First off, as shown in Fig. 5, adaptive learning as an approach, solution or method has experienced a significant rise in terms of scientific publications over the past few years. This demonstrates, in light of the findings of numerous studies (See Table 4), that this field is one of the trends in scientific research, which may be explained in part by the fact that adaptive learning has significant potential to improve the educational field.

Ref.	**Research presentation**	**Citation and Affirmation**
[Bozkurt et al., 2021]	Systematic literature review of 276 AI studies published to between 1976 and 2019.	"The SNA and text-mining analysis uncovers the different thematic topics currently researched on AIEd. Adaptive learning and personalization of education through AI-based practices..."
[Zhang et Aslan, 2021]	Comprehensive review of 40 empirical studies linked to AI technologies for education and published in 1993–2020.	"a lot of research focused on intelligent tutors or personalized learning systems/environments"
[Ezzaim et al., 2022]	Literature review of 32 articles published between 2019 and 2022 related to the applications of artificial intelligence in education.	"In terms of the most common system in our data sample, which can be considered as a research trend in the field of AIED, we cite adaptive learning systems, which represent 33% of all systems".

Ref.	Research presentation	Citation and Affirmation
[Chiu et al., 2023]	Systematic review of the literature of 92 articles published on AIEd between 2012 and 2021.	The authors of this study noted in section 4.1.1 that delivering adaptive teaching methodologies and enhancing adaptability and interactivity in digital settings are two of the major educational domains.
[Ezzaim et al., 2023]	A Survey of Current Scientific Research Trends based on 400 calls for thesis projects and calls for papers between 2019 and 2021.	"artificial intelligence and especially the sphere of adaptive learning is one of the most requested categories by researchers"

Table 4: Studies have shown that one of the trends in education is adaptive learning

Therefore, before we could get into the meat of our discussion, we needed to address the first issue, which was to determine how adaptive learning is characterized today.

Adaptive learning, as the name implies, adapts the teaching-learning process in terms of material, path, presentation, method, and so on to the learner's various needs (cognitive, affective etc.). This educational technology, which has passed through many stations (ITSs, AHs, Adaptive E-learning) during its developmental cycle, has now evolved into AI-based adaptive learning, specifically machine learning. In fact, it is the most robust form as it provided effective solutions to classification and prediction issues, respectively when modelling and categorizing learners, as well as predicting the best learning path for example, which indicates the dominance of supervised learning algorithms in our sample, as shown in the Fig 11 and Table 5.

AI algorithm	Number of studies
Decision Tree	8
Naïve Bayes	5
Hidden Markov	4
K-Nearest Neighbor	4
Bayesian network	3
Support Vector Machine	3
Convolutional Neural Network	2

Table 5: Most AI algorithms used in the extracted studies

Through this mapping, we have also selected numerous research objectives of adaptive learning studies, which will allow us to answer the first research question. The major aims of all the research gathered are to increase performance, motivation, learning efficiency, and achievement through adaptive learning, proving the direct impact on the quality of the learning process. There are also other issues that are rarely discussed but can be addressed through this educational technology, such as improving collaborative learning and help-seeking behavior, as well as the ability to deal with the

cold start problem, which refers to learners being categorized at the first interaction with an adaptive learning system.

The second question refers to how these goals will be met. Adaptive learning systems, in particular web-based platforms, are the most generally used solutions, as demonstrated in the result section, more especially the Fig 9, due to their flexibility and capacity to be utilized on a variety of devices and in any location. Then came recommender systems, which have gained popularity in education during the past few years [Ugarte et al., 2022]. These systems evaluate behaviour using machine learning, and other AI techniques in order to recommend new learning materials that fit their interests, competencies, and level of expertise [Urdaneta-Ponte et al., 2021]. Given its numerous benefits in terms of personalisation, immediat feedbacks, and better motivation, which are illustrated in the findings section, intelligent tutoring systems represents one of the best practices of adaptive learning [Zatarain et al., 2020, Chrysafiadi et al., 2021]. Furthermore, adaptive educational games that provide virtual environments and playful educational scenarios have begun to incorporate the notion of adaptation based on user engagement and devised or chosen problem-solving methodologies; this approach also allows implicit detection of learner preferences. As previously stated, learning adaptation is generally based on the learner's needs, with two broad categories: Affective factors such as learning styles, preferences, and so on, which are determined through dedicated psychological tests or more developed methods based on interaction or classification and prediction through machine learning algorithms. Cognitive factors with a preponderance of prior domain knowledge, responses and performance detected through a pre-test. As a direct response to the second question, adaptive learning goals such as learning improvement are typically solved through online adaptive learning systems and recommendation systems based on the learners' dominant learning style, as well as their current performance and knowledge, detected using interactions and supervised machine-learning algorithms (See Table 6).

Adaptive factors	**Number of studies**
Learning styles	25
Domain knowledge	18
Preferences	10
Learning behaviour	9
learner’s performance	8

Table 6: Most adaptive factors taken into account in the extracted studies

Our findings and mapping have helped us obtain a better knowledge of this educational technology, while providing an opportunity for future researchers to better select the AI-based adaptive learning solutions for each application. In this respect, we can estimate the impact of current research on future adaptive learning techniques as well as the target of our future research. In addition, the following are the broad conclusions on which we have relied. Firstly, the attention paid by researchers to this area, which is evidenced by the increasing amount of research related to adaptive learning. Second, the positive influence of this technology on a variety of characteristics, including learner performance, engagement, and results, as well as the

high level of adaptability given by these systems, are significant advantages that stimulate additional research in this field. Finally, the limits of prior studies are another motivation to seek for other, more effective solutions to issues such as:

- The lack of study in the secondary education compared to higher and primary education.
- The evaluation of some adaptive systems based on a single factor.
- The use of static surveys to identify the learner learning style.
- The remarkable lack of assessment adaptation, even though this phase is an integral part of the learning process.
- The insufficient use of adaptive learning based on new pedagogical approaches such as flipped classrooms, blended learning etc.
- The significant shortage of research related to this field in African countries.

The goal of our future studies is then to meet the need for scientific research in this fertile field. To this end, we intend to conduct experiments in the context of secondary education in Morocco. This country, which has implemented framework law 51-17 adopting the 2015-2030 reform strategy, which is generally based on the intensification of learning through modern educational technologies, and which is considers artificial intelligence as one of the pillars of the national development strategy 2030, which is part of its policy and orientation [Dahir, 2019].

These experiments will be carried out using existing AI-based adaptive learning systems and then develop our own environment, in order to have the possibility to select the optimal machine learning algorithms adapted to the desired objective and to better manipulate the adaptation factors, so as to achieve the best potential results.

6 Conclusion

Using 93 studies published between 2000 and 2022, we conducted a systematic mapping of the literature relevant to AI-based adaptive learning. We have deduced that adaptive learning is a promising area of research, particularly when artificial intelligence is used as a valuable tool. In this regard, adaptive learning platforms based on web technology and supervised machine learning algorithms are the most extensively employed to handle the issues. Given the excellent influence of this educational technology on the teaching-learning process as well as learners' performance, the use and research of such systems has increased since 2019, which could be related also to the impact of the Covid-19 pandemic, namely there is no concrete evidence to support this claim. As a result, while we understand that further study is required to prove a direct link, we acknowledge the possible impact of the pandemic on the increased usage of instructional technology. On the other hand, the majority of this kind of systems rely on learner cognitive aspects to adapt learning.

The following contributions emerged from our literature review as well as the mapping of recent research on AI-based adaptive learning. First, we began by outlining the motivations for doing this study. Second, an overview of adaptive learning's history has been provided, followed by numerous writers' definitions of adaptive learning. Finally, we've discussed the various environments and approaches that have been used

in this regard, as well as the findings of a body of study on the subject. The key findings of our study include the annual number of publications in this field, the distribution of publications by continent, the most common types of AI-based adaptive learning interventions and environments. The analysis of the AI algorithms most frequently used in the collected research, the educational levels with the most experience as well as the objectives and factors involved in achieving them, are also part of the results. Such a study is important for understanding AI-based adaptive learning systems, identifying optimal solutions, issues and challenges, and the state of scientific research in this area.

Future research will address the limitations mentioned above, both in terms of the research strategy adopted and in terms of the characteristics of the AI-based adaptive learning system used. The development of systems that take multiple factors into account during adaptation, the increase in the number of research studies at the secondary level in Morocco, and the application of this adaptive learning approach in the service of one of the new pedagogies while taking into account the most cost-effective pedagogical trends, are all targeted. In addition, experiments will be conducted to compare the impact of several existing AI-based adaptive learning systems, as well as the integration of this technology in several learning phases.

It should be emphasized that our study has certain limitations, including the keywords used to produce the search strings, which may include other terms such as "machine learning," "AI-based adaptive learning," "AI-based adaptive learning systems," and so on. Second, because of the restricted number of databases and studies used, future study can concentrate on additional databases and more scientific papers. Finally, in future investigations, the study exclusion and inclusion criteria will be more stringent. These constraints will be taken into account in future studies.

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