

Personalized Adaptive Learning Management System Based on Bioinspired Algorithm: A Systematic Review

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Abstract. It is possible to address learning challenges in a way that is unique to the needs and preferences of students through adaptive learning environments. Using these platforms, learning content can be personalized to reflect a user's interest, past knowledge, present abilities, and strengths and limitations. Conversely, the efficiency of adaptive learning systems depends on the techniques adopted to classify and present the content according to students' needs and preferences. Artificial Intelligence (AI) techniques have recently been applied in personalized adaptive education systems to address content delivery-related learning challenges. However, not much is known about content adaptation based on bioinspired optimization algorithms. This study offers a comprehensive evaluation of the literature on personalized adaptive learning Management systems based on bioinspired optimization algorithms. The study examined conference proceedings and journal papers published in Scopus, Web of Science, and IEEE databases between 2013 and 2023. Nevertheless, Web of Science yielded no papers that were connected to this investigation. Web of Science was thus left out of the research. 5442 were screened in total, 303 were evaluated, and 6 were deemed eligible for the systematic review. Our findings suggest that there have been a limited number of research or personalized adaptive learning systems based on bioinspired algorithms.

Introduction

The rapid advancement in artificial intelligence (AI) technologies has led to significant interest in their ability to address challenges in every field and education is no exception [1]. The emergence of sophisticated AI-enabled learning systems is gaining popularity, due to their ability to deliver learning content and adapt to their specific requirements [2]. AI is a technology that seeks to mimic human behavior by interpreting human activities and producing desired results. Therefore, the ultimate goal of AI is to perform tasks that would otherwise require human intervention [3]. AI will play a bigger part in higher education since it allows students to approach learning challenges in a way that is specific to their preferences and experiences [4]. Thus, one critical goal of AI in Education is the provision of personalized learning that maximizes learning with tailored guidance or support depending on learning status, preferences, or personalized traits [5]. In addition, AI-enabled learning systems can be used to predict learning performance, attrition, and relevance, enabling instructors to detect at-risk students and provide timely intervention [6]. However, despite the fact that these modern learning systems are helpful as educational tools that satisfy student needs, there are not many systems in place that are intended to address the concerns and problems faced by many students [2].

The quality of knowledge is the most important task of a learning system at any level and stage of education [7]. In addition, the learning process has become more convenient due to digital learning platforms such as Learning Management Systems (LMS) as indicated in Fig. 1 [8]. For instance, to improve online learning capabilities, LMS has been embraced by the majority of universities, organisations, and institute worldwide. It is a tactical approach to organizing, producing, delivering, overseeing, and maintaining educational events or courses [9]. However, current LMS do not consider students' individuality regarding their various levels of input knowledge and skills or their different learning styles [10]. Moreover, the quality of LMS also offers a dynamic platform for fostering communication between teachers and students [9]. Hence, the use of adaptive knowledge control has

become relevant in considering the individual level of knowledge of the learners [7]. Although, a personalized adaptive learning is an efficacious method that leverages on technology to promptly modify instructional strategies based on learners' specific variations and shifts in traits, output, and personal development in real-time [11]. Thus, in light of student's objectives and level of expertise, an adaptive learning system seeks to alter the way the content is delivered to a specific student [12].



Fig. 1. Learning management system model.

Additionally, an effective adaptive learning management system can give fast, accurate, and highly targeted feedback during problem-solving. This means that it can organize the content according to the unique skills of each student [13]. Typically, an adaptive platform facilitates personalized learning and has the potential to boost learning outcomes and improve the student's learning experience and it represents an opportunity to ensure equity for all students globally. Thus, adaptive learning environments are essential in addressing the large-scale personalization for real-world human learning processes [14]. In this regard, there are a number of AI techniques and approaches that can be utilized to evaluate educational data, to explore instructor and student actions in identifying behavioural trends and translate the educational data into insights that can be leveraged on to enhance the learning experience [13]. For instance, Deep Learning (DL) and Machine Learning (ML) are two subsets of AI, that are thought to revolutionize the field of education. Thus AI, including ML, and DP techniques can be applied to education data to enhance digital education [4].

[11] has established from previous literature that AI techniques and approaches have been employed to classify and collect student data based on their needs and attributes. Furthermore, the way in which the data is processed to create an intelligent and adaptive learning environment determines how effective a personalised adaptive education system will be. In this regard, the techniques and approaches rely on algorithms to automatically and dynamically map the behavioural traits of students to a particular approach of learning with the goal to optimise each student's unique learning experience [11]. Other examples of learning-related AI techniques are Artificial Neural Networks (ANN) known as one of the deep learning techniques, Naïve Bayes and Random forest classification in data mining, Support Vector Machines (SVM), decision trees for classification, regression and outlier detection. Furthermore, knowledge-based reasoning and inquiries can be guided by metaheuristics in complex scenarios and challenges, allowing the mediation of more precise, effective, and dependable answers. Further, conclusions from past and current information could be drawn using inductive and deductive reasoning [3]. Another developing crucial element of LMS is Learning Analytics (LA), and deep learning-based approach that tracks and logs student activities in higher education's online environment to improve instructions. Therefore, based on the students' log activity that an LMS provides, LA assesses the gathered data and forecasts student performance. The main goal is to identify students who are at risk so that timely and suitable interventions can be given [15].

Bioinspired Algorithms

Nature serves as the source of inspiration for bioinspired algorithms. Similarly, these algorithms are also called metaheuristics and are based on the same fundamental concepts of animals, birds and plants behavior [16]. Therefore, solving complicated real-life problems has become a crucial duty in modern-day society. Many of these constitute combinatorial problems, where finding optimal solutions is preferred than finding exact solutions. It has been established that traditional optimization techniques work well for small-scale problems. Therefore, conventional approaches either don't scale up well enough to solve large-scale problems in the real world, don't produce the best results, or only provide answers after a lengthy process. Furthermore, even previous AI-based methods used to solve the issues were unable to produce satisfactory outcomes [17]. Moreover, despite the fact that numerical approaches have been frequently employed to solve optimisation problems, their precision depends on the selection of an initial solution. Additionally, analytical methods are almost of no use in real-world applications due to unknown spaces and the complex, non-convex character of the problems. As a result, a unique class of intelligent search algorithms such as metaheuristic optimisation techniques has been developed in response to the shortcomings of analytical mathematical methods in problem-solving [18]. These methods, also termed bioinspired algorithms that drew inspiration from the characteristics and behaviours of organisms have yielded a wide range of usefulness. Through simulations, they have been theoretically proven and implemented [17].

Therefore, Bio-Inspired Optimisation (BSO) techniques facilitate the resolution of difficult optimisation problems while simultaneously addressing the drawbacks of traditional optimisation strategies [19]. In addition, BSO is recognized as a nature-inspired evolutionary algorithm for feature selection among several well-known conventional feature selection strategies. It converges to a global optimum rather than a local one and has a low computing cost [19]. Its local optimal avoidance property aids in the search for global solutions. In metaheuristic approach utilization, the task is split into two phases: exploration and exploitation. Exploitation is the process of focusing on a particular area to identify the best answer in the area, whereas exploration is the search for larger areas with potential solutions [17]. Moreover, the notion of exploration denotes the algorithm's capacity to search the space globally to find the ideal area, while the notion of exploitation denotes the algorithm's capacity to search the space locally to converge a better space. Therefore, achieving an equilibrium between exploration and exploitation is necessary in identifying the best optimal solution [18]. Overall, to optimize an existing LMS learning platform and address concerns about its adaptability, new computing methods built on BSO algorithms or evolutionary concepts must be adopted [20]. It is important to note that the high computational complexity and delayed convergence rates of BSO algorithms are their drawbacks. However, these disadvantages can be overcome through hybridizing with other approaches and techniques to enhance the performance of BSO algorithms and prevent premature convergence in the future [19].

Methodology

Since the results of our search were limited, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) steps were altered for this inquiry. PRISMA mandates that a substantial sample of data must be scrutinized and evaluated. Thus, as illustrated in the six phases in Fig. 2 below, we used the Systematic Literature Review (SLR) approach. With the use of this technique, a thorough literature search was carried out in the bibliographic databases IEEE and Scopus, which include academic writing from almost every discipline of study. We also considered and searched Web of Science database. However, we found that there were no publications about bioinspired algorithm-based personalised adaptive learning management systems. Moreover, SLR is an important tool for carrying out thorough systematic reviews, since it helps to pinpoint gaps and investigate novel research exploration. As a result, SLR is a tool that may be used to create, assess, and analyze outcomes for a specific topic [21, 22]. Therefore, the focus is on accurately extracting high-quality data from a pool of data to ensure excellent reporting [23]. In this regard, the SLR was used in this study to assess the body of information that is currently available for professional practice and identify any knowledge gaps in the area of study [24].

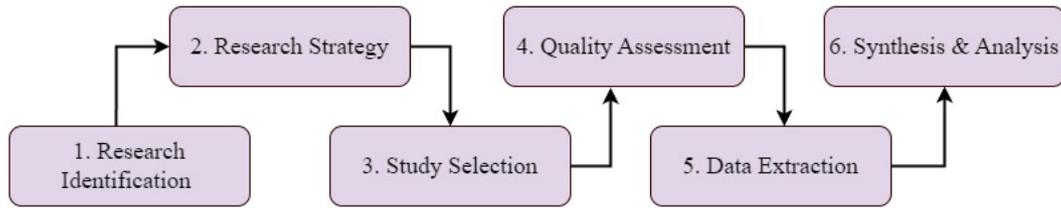


Fig. 2. Systematic literature review method.

The six phases involved in conducting a systematic literature review are as follows:

- 1. Research Identification.** The objective of this study was to focus on studies related to personalized adaptive LMS based on bioinspired algorithms. Furthermore, the goal of the SLR was to identify a gap in adaptive learning management systems (LMS) using bioinspired algorithms.
- 2. Research Strategy.** The study relied on Endnote referencing for organizing, screening and bibliographic management. Moreover, Endnote is useful in capturing the reference details during the screening of the articles and conducting searches from multiple sources [21]. Additionally, the following keywords (Adaptive Learning Management System, Adaptive Personalized Learning, Personal Learning Environment, Bioinspired, optimization algorithm, Metaheuristic algorithm and Bioinspired intelligent algorithm). These keywords were used to extract articles from the databases.
- 3. Study Selection.** The publications in this section were chosen based on inclusion and exclusion criteria that stated only English-language papers published in scholarly journals would be taken into consideration, as well as papers that were pertinent to the context of the study and contained novel findings that warranted additional investigation. Conversely, non-accessible journal publications were not included. As a result, six published journal articles and conference papers made up the final selection. Additionally, reviewing the article's title, abstract, and body helped determine how relevant the article was to the context of the search. As a result, 1066 were screened, 441 articles were assessed and evaluated, and 6 qualified for the systematic review. Furthermore, every publication that was included in the systematic review process was considered and pertinent to the research project [21].
- 4. Quality Assessment.** In this section, we assessed the robustness and credibility of the article selection process using quality criteria. In terms of systematic review analysis, the criteria taken into consideration for evaluating the articles on the research paper that were extracted from the databases adequately addressed the research-related insights.
- 5. Data Extraction.** The articles were selected from the IEEE and Scopus databases as indicated in the methodology section above. Furthermore, the articles were considered on the basis of the inclusion and exclusion criteria. Thereafter, data was extracted from the qualified articles as explained in the next step, number 6.
- 6. Data Synthesis and Analysis.** This section elucidates the methodology used to undertake the modified PRISMA approach to the SLR method in light of the small number of publications included in this research paper. In addition, step 2 indicates the keywords and databases used for this study as mentioned in the methodology section. In step 3, which is the selection phase, we had initially retrieved 1377 articles from both Scopus and IEEE databases. 36 items, however, were eliminated as duplicates. Thereafter, 1066 records were screened. Step 4, represents the quality assessment stage. In this step, data synthesis and analysis, 441 articles underwent assessment and evaluation. Thereafter, 6 publications were then determined to be eligible for this research paper.

Results and Discussion

This systematic review discusses the six studies that are relevant to our research project. Data was collected using the methods described in the methodology section of the six included articles, four articles employed bioinspired algorithms, one depended on the Learning analysis method, and the other on selection criteria. Four of the articles were conference papers, while two were published in

electronic journals. As Table 1 shows, these articles were the primary source of information and were published in scholarly journals. Furthermore, Table 1 lists the adaptive techniques and datasets employed in the chosen studies. Each study used a different approach to modify the online learning management system. Additionally, to investigate the distribution of the research publications, we employed statistical analysis. As seen in Fig. 3, the distribution of the research publications was as follows: India in 2013, Serbia in 2021, China in 2021, Thailand in 2021, Malaysia in 2021, and Kazakhstan in 2023. On the other hand, Fig. 4 shows how publications are distributed by year. Each country produced one paper. Further, we were able to establish significant facts about personalized adaptive learning management systems based on bioinspired techniques. For example, we collected information on how bioinspired algorithms are capable of offering the most efficient solution. Furthermore, based on this research paper the findings indicate that the usage of personalized adaptive learning environments based on bioinspired algorithms is promising and growing. In addition, the research paper revealed the significance of using bioinspired algorithms for deploying innovative E-learning mechanisms in higher institutions of learning. This concurs with [20] who emphasizes the importance of considering new computing methods built on BSO algorithms or evolutionary concepts to optimize an existing LMS learning platform and address concerns about adaptability.

Table 1. Presents the adaptive methods and dataset.

Author	Adaptative method	Dataset
[25]	Learning analysis methods	Activity report activity report
[26]	Selection criteria	Assessment scores
[27]	algorithms based on a unified artificial immune system (UAIS)	Statistical data
[28]	Particle swarm optimization (PSO) and Jaya algorithms	Discrete data
[29]	metaheuristic algorithm of Particle Swarm Optimization (PSO)	Real data
[30]	Genetic Algorithm (GA) and Ant Colony Optimization Algorithm (ACO)	Course and jobs

Fig. 4 shows the number of published articles for each country. Each country produced one paper.

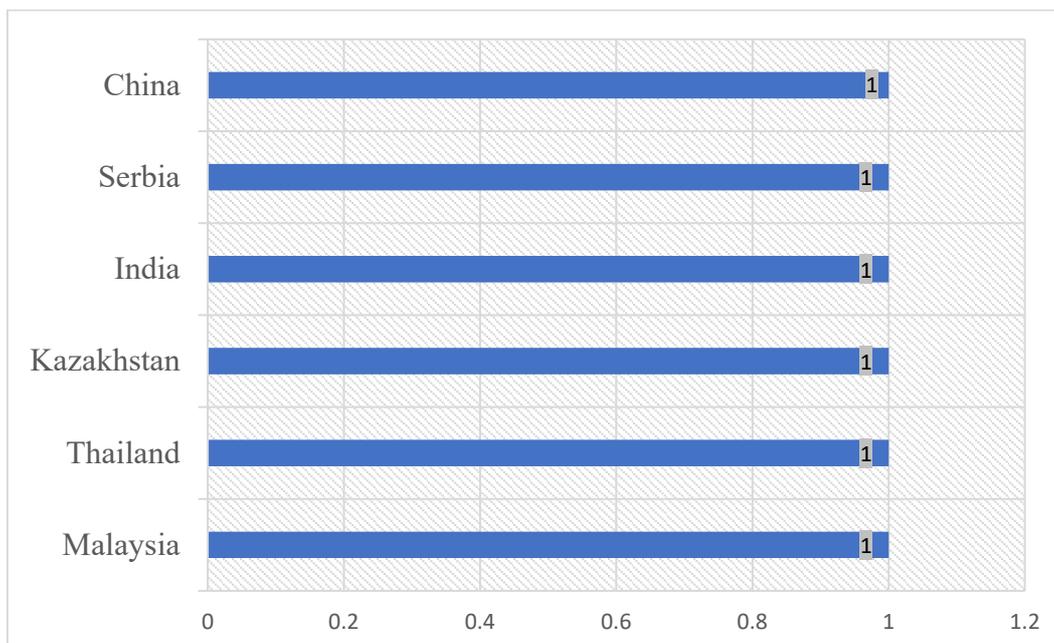


Fig. 3. Publication per country.

Fig. 4 displays the total number of selected published journal articles per year. Further, 1 journal article was published in 2013 and 2023, and 2 journal articles were published in 2021.

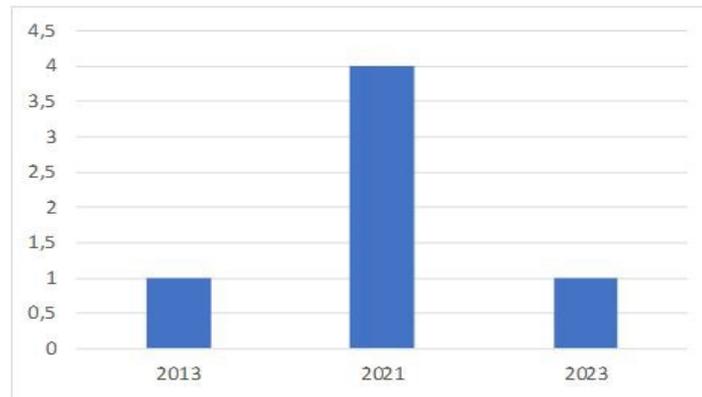


Fig. 4. Number of selected published journal articles between 2013 and 2023.

[25] work was able to show that the learning analysis method may be used to provide adaptive learning. According to the study's findings, learners of the two styles differ in the order of their learning behaviours but not much in their performance and that there is a difference in the critical behaviour sequence that predicts learning performance. On the other hand, [26] relied on the selection criteria which consisted of learning style preferred language of reporting and assessment method. Conversely, [29] demonstrated that Particle Swarm Optimisation (PSO) may record, examine, and group data according to individual performance concerning precision, effectiveness, and level of understanding. The technique of carrying out the simulation involved actual data that was gathered from students. Notably, [28] used the Jaya and PSO algorithms to automatically create collaborative learning groups, to improve the efficiency of online learning as a whole. When compared to PSO, the Jaya algorithm proved to be the best option. A multi-objective optimization model was created in a different study by [30] to determine the best learning paths. The results indicated that, in terms of efficiency, the Genetic Algorithm (GA) performed slightly better than Ant Colony Optimisation (ACO) in providing the runtime response for a single request. In a similar study, the complexity of personalizing courses for individual students was addressed by using an algorithm based on the Unified Artificial Immune System (UAIS) [27].

Conclusion

In this research paper, we presented a comprehensive systematic literature review on personalized adaptive learning management systems based on a bioinspired optimization algorithm. Our findings indicate the scarcity of personalized adaptive learning management systems based on bioinspired optimization algorithms. The results of the studies in this systematic review indicate that further research is required to examine alternative research directions to improve the quality, impact, and pace of convergence of the suggested algorithms. Furthermore, scholars and researchers may utilise a hybrid algorithm that blends both conventional and bioinspired methods to address the challenge posed by the complexity of learning management system adaptation.

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