

**Systematic Review of Adaptive Learning Technology for Learning in Higher Education**

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The current study utilized a strategic search approach based on publishing trends, instructional, research methodological components, research emphasis, and adaptive techniques and technology. During the last one decade, several peer-reviewed articles have addressed to different dimensions of this domain area. However, there is a lack of a comprehensive and systematic narrative which can portray a review of studies and literature on this subject. This paper is an attempt to review the existing literature of recent times on adaptive learning technology in higher education. A total of 112 studies on adaptive learning were assessed to characterize the status and identify literature gaps. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a

systematic search was conducted using key databases to ensure the identification of all relevant articles. Documentation of many descriptive criteria, such as publishing trends, educational environment, and study technique components, was made available. The current study looked at the study focus, adaptive tactics, and adaptable technology. In some studies, the authors also looked at the design, development, implementation, and assessment processes. The authors used content and instructional models as well as adaptive sources to investigate adaptive approaches. The most widely investigated adaptive objectives were learner characteristics such as learning style and adaptive feedback and navigation. The findings of this study, which highlight research gaps for adaptive learning designers and researchers in the future, will be useful. To discover more about how adaptive learning might help people learn and advance, more study is needed. The lack of didactic literature on adaptive learning and the need to integrate domain expert knowledge emphasized the necessity of this research. This review adds to the body of theoretical reviews in the analytics literature of this domain. While prior theoretical reviews were restricted to methodological challenges and techniques and a relatively narrower application of adaptive learning, this study attempted to widen the application areas by making use of varied implementation techniques and a qualitative assessment of literature and a systematic selection and analysis of research studies.

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Introduction

Adaptive learning as an educational technology is a kind of scaffolding technique customized to help all stakeholders in an educational institution, teachers, students and school administrators (Castañeda & Selwyn, 2018). For teachers, Adaptive learning technology saves teachers time and provides them valuable data about each student's level of progress and their capability to learn. Adaptive learning serves as an assistive platform that enables them to plan an effective personalized teaching experience for every student, build customized resources and activities that address each student's unique learning needs. Also known as assistive scaffolding, it requires teachers to adopt differentiated instruction principles and deliver content that suits each student's learning process. For students, adaptive learning technology allows each student to get the instruction and practice faster and suiting to their capability. Due to scaffolding technique involved, students receive individualized instruction which help them develop their personal potential in and out of the classroom. Besides, adaptive learning helps students to learn through personalized methods based on each student's current skills and performance and receive immediate feedback based on each student's strengths and weaknesses (Castro, 2019). For school administrators, adaptive learning is a good solution to their budget constraints, as this platform provides a variety of high-usage cost-effective options – or if they face the challenge of low student test scores it can increase pass rates, lower fail rates, and accelerate student proficiency. Adaptive learning is also an edtech tool that offers complete ownership to teachers and staff. Aleven et al. (2016) opined that adaptive learning helps teachers develop and deliver content, reflect on its effectiveness, and adapt it to the specific needs of students (Pitts, P. J. 2022).

There are three levels of adaptivity in order to make teachers feel empowered: adaptive feedback of students' current state of knowledge, adaptive pathways that define the content delivery, and the adaptive ability of teachers to adapt their teaching based on the data analysis (Weber, 2019). Students learn at varying rates, they make mistakes; they forget what was taught in the classroom, they get confused with technical terms and formulas. Teachers can provide instant feedback to students so that they can learn to address such challenges. students also have different levels of knowledge, and therefore develop different misconceptions. Teachers can use adaptive platforms to provide them resources and content to help them better understand the concept. If required, the teacher can also provide each student a customized learning path based on their demonstrated understanding of a topic.

Adaptive learning adopts a technological outfit when it encourages teachers to use research inputs to shape the in-program content and their pedagogy. Adaptive learning technology equips them with the ability to continuously improve their pedagogy and use analytics to better understand their students' learning abilities and understand their learning behavior. Often, adaptive learning needs to use a blended and online learning environment, to provide a personalized learning experience. Such an environment is equipped with technological innovations such as learning analytics and machine learning, or systems that monitor learner progress and use data to continuously modify the teaching content according to the needs of individual learners (Becker et al., 2017).

Adaptive learning systems are of various types, ranging from simple systems based on a preconceived set of rules to complex systems with self-learning algorithms. There exists no scientific evidence to support its effectiveness (Castañeda & Selwyn, 2018). Since it considers the unique characteristics of each student, an adaptive learning method is more engaging and memorable for students of all ages and abilities in a variety of educational settings. An adaptive learning framework, instructions, and adaptive teaching techniques can also be used to accomplish adaptive learning (Castro, 2019). In higher education, adaptive learning has been both a scientific and technical advancement. Fast feedback, remediation, metacognition, and mastery-based learning are just a few of the many educational advantages of this system (Martin et al., 2020). According to Alevén et al. (2016), it aims to provide students with "automatic, dynamic, and interactive" information in the classroom.

Utilization of learner preferences such as visual presentation of materials is possible to impact how instructional information is delivered in adaptive learning (Osadchyi et al., 2020). In mixed and online learning environments, where adaptive learning is the norm, students receive a more tailored education. Students' shifting needs may be met through the use of data analytics and machine learning, which allow instructors to constantly adjust their educational materials to meet those needs (Kasinathan et al., 2017). This has led to the increase in the popularity of adaptive learning technology, but still widespread implementation remains a challenge (McCullough, A., Patrick, K., & Boni, A. A. 2022).

Higher education institutions, according to previous research, face a range of challenges when assessing or adopting adaptive learning methods. In the literature, three main types of barriers discussed are those relating to technology, instruction, and management (Nodine, 2016). Learning management systems (LMS) integration issues, real-time data challenges, and the complexity of adaptive systems are a few technological hurdles. In previous studies, it was shown that the literature on adaptive learning is typically fragmented or presented via certain lenses. Furthermore, it is still not clear which implementation concerns need the greatest attention. A last point to make is that when it comes to addressing educational issues, the views of just a few countries (such as the United States, the United Kingdom, and Australia) depend significantly on adaptive learning (Xie et al., 2019). It is possible to utilize this strategy to rethink important factors that impact acceptance of technological improvements in educational settings, discover new ones and gain a new perspective on the adoption problem.

There is a dearth of empirical research studies on adaptive learning, as adaptive technology is still in its infancy (Weber, 2019); however a few early studies have measured the effects of adaptive learning on students' learning outcomes (Bailey et al., 2018; Holthaus et al., 2019; Yarnall et al., 2016) and fall in dropout rates (Daines et al., 2016), recognizing the potential of adaptive learning to improve student success (Green, 2018).

Higher education institutions have reported challenges in implementing adaptive learning, mostly related to technology and its usage (Bailey et al., 2018), pedagogy and program delivery (Johnson & Zone, 2018) data analysis and management issues (Zliobaite et al., 2012) and integrating adaptive learning solutions with online learning platforms like Blackboard (Bryant, 2016; Dziuban et al., 2018). Educationists have also faced challenges

related to designing curriculum according to the adaptive learning requirement (Educause, 2017) and the role of faculty in its implementation (Bryant, 2016; Oxman & Wong, 2014). In its initial stages, while some faculties showed resistance towards using technology (Johnson & Zone, 2018), others expressed concerns about outdated course design and additional workload (Giesinger et al., 2016; Izumi et al., 2013). A few studies have highlighted lack of experience of the teachers with adaptive technologies responsible for their disengagement and disillusionment (Johnson & Zone, 2018; O'Sullivan, 2018). A few studies brought attention to the challenges faced by administrators and managers, related to incompatible university strategy to support goals of adaptive learning (O'Sullivan, 2018), lack of leadership support, and insufficient financial and personnel resources (Bailey et al., 2018; Johnson & Zone, 2018).

Previous studies have examined the significance as well as challenges of adaptive learning. However, they remain fragmented, with no systematic classification of adaptive learning practices in higher education. The current study is only a comparative study across different theoretical and empirical studies which aimed to familiarize readers with its research significance (A. M. Johnson et al., 2016) and the maximum variation of its properties (Creswell & Poth, 2018). One advantage of reviewing these studies is to learn about factors that are required for the successful implementation of adaptive learning. These studies in Adaptive Learning have previously examined how important it is for e-learning systems to be flexible so that students can take charge of their learning. Due to this, the focus of these reviews has been on adaptable criteria, such as individual differences, personal characteristics such as learning styles, and the effectiveness of adaptive learning.

There is also the lack of a comprehensive systematic review of studies on adaptive learning. The current study compiled a systematic review of the published articles to evaluate first the significance of adaptive learning as seen by critics and experts and then investigate whether it is an ideally suited to the present-day university environment. It is hoped that this study will be a contribution to the domain of adaptive learning and offer a more comprehensive and systematic approach to its study.

Methodology

Several literature reviews about adaptive learning were searched and it was found that a detailed review was essential to combine all the results of these studies and drive a conclusion about the ambiguities and misunderstandings. The studies were classified and aggregated as per the recommendations of Cooper and Koenka (2012)'s PRISMA (i.e., Preferred Reporting Items for Systematic Reviews and Meta-Analyses). In the first step, the problem was formulated about how adaptive learning could be designed, developed, implemented, and assessed in universities. This research question was further elaborated to examine whether the adaptive learning possessed enough content and instructional models that could help investigate adaptive approaches in higher education learning. While performing the search process, a search chain or query links were created of each database. It was necessary to vary the syntax of each search criterion or query in accordance with the database. Hence, the series of concepts using the connectors AND/OR resulted in a very useful search string.

The search process was performed on two recognized educational databases for both primary and secondary studies namely (ERIC and Educational Research) for published articles between 2015 to 2020 in two phases. During the first phase, the authors kept the focus on research in education and its characteristics in the development of adaptation for learning. A blend of specific terms was used in the research study, taken from the title, abstract, and keywords like “adaptive learning” AND “Adaptive technology in higher learning.” Boolean operators, parenthesis and truncations were used whenever appropriate. Synonyms of key words were also used in some exceptional cases, to achieve a more comprehensive search.

The English language was the only language that was selected for the literature search. Inclusion and exclusion criteria were defined for both the phases of the search procedure: The eligibility of articles for this overview depended on the inclusion and exclusion criteria selected for this study namely the articles must fall between 2015 to 2020; the articles included were only peer-reviewed ones or were reports, dissertations with technical reports. The primary focus of the selected articles should be on adaptive learning technology in higher learning; and all articles selected were written in English.

Prior to the selection process, duplicate papers were also excluded. The papers published in two journals with the same title, same first author, same study design, sample size, and the same number of in-text citations or references were referred to as duplicate papers. We performed thorough research to identify any such paper and did not include in our review. The principal author's name was used for reviewing every retrieved research paper for inclusion and exclusion. Moreover, full texts were also retrieved for all such authors until a resolution was reached. The papers included in the research were searched again to find more research articles. The papers that were retrieved again passed through the same screening procedure to ensure and increase the authenticity of the research.

The search in the second phase was also started with same keywords and same databases with time filter January 2019 to April 2020. Journal articles written in English were added as additional filter at this stage. Operational definitions of each keyword were also found in the selected articles during this phase. The final analysis provided articles with summary, facts, and remarks made by reviewers. The exclusion criteria dealt with (i) reviews that did not conduct any systematic search (i.e., literature review), (ii) not peer-reviewed, (iii) not focused on adaptive learning, (iv) not related to adaptive technology and (v) not published in English. Duplicate articles were removed prior to the selection process. The first author was responsible for screening each retrieved article on the title and abstract for inclusion and exclusion. A primary goal of this exclusion was to eliminate papers that solely dealt with technical elements of adaptive learning according to the context of computer area and engineering. The next section presents the results of the current study.

Results

To make the screening process efficient, the eligibility phase was reached as per the PRISMA review process. A total of 112 articles were found primarily from the selected databases. After removing the duplicates, 70 remained to be screened. After the initial

screening was complete, 23 and 10 articles were excluded after title screening and abstract screening respectively. Finally, 13 articles underwent full-text screening and eligibility analysis, after which 10 articles were left for the final analysis. Articles were excluded due to the inclusion and exclusion criteria and the aim and scope of this systematic review. Figure 1 provides the PRISMA flow diagram of the review process.

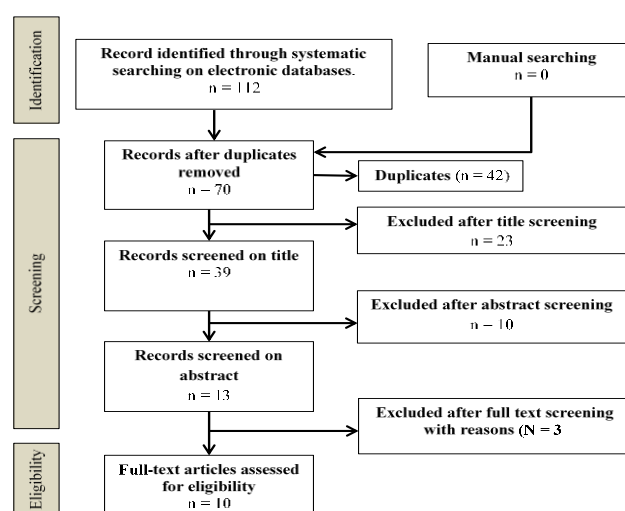


Figure 1: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis)

Articles where a decision could not be made underwent full-text screening; for instance, two studies (Zliobaite et al., 2012) and (Oxman & Wong, 2014) were subjected to full-text screening and eligibility analysis. The objective was to identify whether these two articles followed methodology that could be used to resolve any disagreements and achieve consensus about use of technology in adaptive learning. It was found that they dealt with issues like data analysis and management issues, role of faculty in its implementation, and like. The screening process is illustrated in Figure 1. During the process, the adaptive learning technology was focused upon. The selected articles dealt with both design and implementation of the adaptive learning programs. A manual hand-search of the reference list of the included review articles was also conducted simultaneously, which however resulted in no further potential articles.

A matrix table was prepared to display each selected paper. A descriptive analysis was done to review each article. After the descriptive analysis was done, the articles were then compared as Cooper and Koenka (2012) suggested. The authors' names, the study's objectives, the number of studies with the feedbacks, the identified number of criteria, and the results and feedback, were retrieved from the literature reviews. While the analysis was carried out, the data was collected to verify and validate the solutions and results. This analysis was done with the help of identification and description of the issues for every keyword.

Table 1 illustrates the 10 studies and reviews that were finally screened through the inclusion process using the PSIMA method. These studies and reviews support the use of adaptive technology in universities

Table 1

Characteristics and observations from the selected articles.

	Authors	Year	Summary finding	Time line	Sample size	adaptive strategy
1	Nodine	2019	How competency-based training has evolved inside American higher education	2010–2017	78	Personal traits
2	Kasinathan et al.	2017	It explains the system of adaptive learning for higher education.	2001–2016	78	Learning styles
3	Xie et al.	2019	From 2001 to 2013, a thorough review of individual differences in adaptive learning systems	2001–2013	98	Individual differences
4	Castro	2019	Trends and capacities of blended learning in higher education	2017–2019	70	Learning styles
5	Aleven et al.	2016	The use of adaptive learning tools in the classroom.	1993–2009	52	Learning characteristics
6	Castañeda and Selwyn	2018	Making sense of higher education's continuous digital transformation	1997–2007	15	Effectiveness of adaptive learning systems
7	Bailey et al.	2018	Higher education institutions have reported challenges in implementing adaptive learning, mostly related to technology and its usage	2017–2018	70	challenges in implementing adaptive learning
8	Johnson & Zone	2018	Pedagogy and program delivery	2015–2018	100	Pedagogy delivery
9	Dziuban et al.	2018	Integrating adaptive learning solutions with online learning platforms like Blackboard	2011–2018	40	Integrating adaptive learning with online learning
10	Biten	2017	Resistance towards using technology	2007–2017	50	Faculty resistance

Discussion

In this context, there are two terms: adaptive target and path to the goal. The learner and the content model are both included in the adaptive target. Review studies from the previous decade, which tend to focus mostly on understanding what will be modified, offer an important opportunity for additional investigation. When developing and refining adaptive interventions, instructional designers must go outside the learner model for inspiration.

The study analyzed 112 empirical research published between 2015 and 2020. These articles helped in the identification of current trends and behavior in adaptive learning, especially in research for education. The study by [Yuksel et al. \(2016\)](#) indicated emerging publication patterns and instructional settings in a variety of formal and informal learning situations. According to these findings, educational researchers are increasingly focusing on adaptable learning, which includes studying the demands of adaptive systems (see [Figure 2](#)), studying learner characteristics, creating adaptive learning systems, putting them into practice and evaluating them.

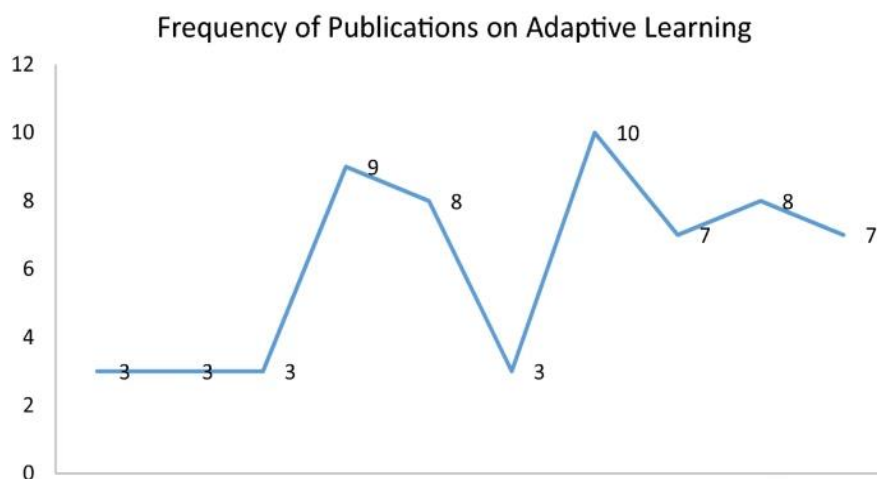


Figure 1: Trends in adaptive learning in higher learning institutions (source; [Alexander et al. \(2019\)](#))

In the prior literature review studies on adaptable learning, these findings contribute by looking on adaptation for learning through broad learning instead of focusing on alternative variables such as learning styles or intrinsic characteristics of students ([García-Peñalvo et al., 2018](#); [Kynigos, 2019](#); [Roberts-Mahoney et al., 2016](#)). As part of their examination of learner characteristics, aside from the learner model's adaptability, [Su \(2017\)](#) includes content and instructional models as well. In contrast to the content and instructional models, the learner model focuses on the qualities of the learner, whereas content and instructional models focus on the properties of the knowledge domain. If a university is going to create adaptive learning environments, it needs more than just a learner model; it also needs to look at how to get there ([Clark et al., 2022](#)).

This analysis finds that adaptive learning studies are increasing, but there is a need for further research in a variety of educational environments. It was found that a large number of studies were carried out in higher education institutions, with Taiwan and the United States coming in second and third place, respectively. As a result of these findings, more research in formal and informal contexts, including K-12 schools, is needed. Technology adoption and online learning in higher education may be to blame for this discrepancy (Biten, 2017). Higher education students, by nature, are better prepared for self-regulation and adaptive learning. Furthermore, researchers in higher education may face fewer restrictions in obtaining data than their counterparts in K-12 or informal settings. Computer science, engineering, language learning, biology and the earth sciences are only a few of the subjects explored in previous works on adaptive learning. Predominantly, researchers employed tests and surveys to acquire data for experimental design studies. However, if more insight into the application of adaptive learning is required, it is necessary to study a wider range of methodologies in this study field.

There are four sorts of adaptable technologies that may be used to help students learn: (1) adaptive learning systems, (2) learning apps, (3) teaching methods and (4) adaptive design solutions. As previously reported by Biten (2017), the majority of the studies reviewed in this article used an existing adaptive learning system or developed, developed, implemented, and evaluated an adaptive learning system, platform, or model to personalize learning pathways. It is estimated that less than 5% of the research examined the usage of adaptable learning applications, such as software that allows instructors to manage the learning activities their students engage in, rather than relying on a system or platform's general adaptability. One or a few adaptive learning systems or apps were investigated many times to determine their perceived value and efficacy in the selected research. Newer learning management systems and platforms, including adaptive learning, are increasingly compatible with one another.

The findings of this review show that Adaptive learning systems were explored by Becker et al. (2017) in their review, however, most of the research focused on specific learner characteristics, such as personal attributes and learning styles (Aleven et al., 2016; Castañeda & Selwyn, 2018; Castro, 2019; Kasinathan et al., 2017; Nodine, 2016; Xie et al., 2019). As a result of this research, it is evident that teaching students how to learn is an important part of creating effective adaptive learning environments, and it can be done by modifying instructional strategies and design to meet the interests, expectations, and abilities of diverse learners (Biten, 2017).

The Felder and Silverman Learning Style Model (FSLSM), for example, has been utilized to identify students learning styles in around 20 percent of the research. In addition to highlighting adaptive teaching and control strategies or sequencing algorithms, this was done to construct specialized learning situations for prototyping purposes. Adaptive learning environments, such as those based on pre-existing frameworks or paradigms, were only mentioned in about ten percent of the research publications. Students' learning styles and requirements were also considered while designing algorithms for individualized learning routes. Teaching methods were also improved through the creation of evaluation tools.

Conclusion

For the most part, adaptive education research has been centered around the learner model. To build on the work of [Su \(2017\)](#), the study gathered and highlighted relevant studies that include not just the learner model, but also the content and instructional models as well. Both instructional methods and content models vary widely in studies that focus on the adaptive objective. In light of this, adaptive learning researchers must take into account both their model's source and their purpose while developing it. As a result of this shift, [Smaili et al. \(2020\)](#) designed a pathway of adaptation which can now receive more attention. Adaptive learning should be the focus of future study, both individually and collectively, to facilitate individual learning and customized progress. There should be an abundance of infrastructure, including the appropriate hardware and software, internet connectivity, and Internet quality. It is impossible to execute adaptive learning without a solid foundation. An organization's executives and the corporate sector or government may collaborate to build a foundational infrastructure for the institution (e.g., inexpensive internet for students). To get the most out of adaptive technology, you need to pay attention to its usability and robustness. They might have a positive effect on the motivation of both teachers and students to adopt adaptive technology.

Personalized learning at scale is made possible through adaptive learning, a promising method of teaching that has a lot of promise to satisfy the requirements of a wide range of students. It can also help underserved groups and areas get access to higher education ([L. Johnson et al., 2016](#)). Adopting an adaptive learning system is difficult to deploy. Although the investment in a significant study into how to enhance its adoption rate will pay off, because the successful adoption of adaptive learning will give a high return for students, institutions, and the area economy, adaptable learning is worth the effort.

Adaptive learning research needs to be more rigorous and diverse, as has been observed in previous evaluations. Although the number of investigations on adaptive learning has been less, the focus of these learning studies is changing according to the context. Adaptive learning interventions have been evaluated quantitatively in most studies, but only a small number of studies have attempted to elucidate how learning progresses for adaptation in order to produce educational benefits, which is likely to be presented in a qualitative research approach. When looking at adaptive learning interventions using experimental designs, it appears that there is a good purpose to find causative behaviors. Future meta-analytic research, however, will be required to consolidate these findings. Other components of adaptability, such as reporting the adaptive techniques or adaptive technology employed, should be examined in future studies, as well. Despite being eliminated from the research sample, only a small number of meta-analyses were omitted from the study results.

There are a few limitations to conduct a systematic review of this nature. For instance, it was difficult to extrapolate the results directly of such experimental studies due to skills and instruments deficiency. Though 10 research papers were reviewed systematically in view of study objectives, simultaneous characteristics (e.g., design and delivery of adaptive learning and implementation of its technology) in each one of them were not present.

Therefore, the variation of the number of included studies for all these characteristics was different. However, despite these limitations, this study will serve as a good source of reference for finding relevant studies and building a point of view on silver nanoparticles and their applications in preventing biofilm formations.

Author Contributions

Conceptualization, J.L.R.M; F.M.O and D.L.A.J; Methodology, all authors; Resources, all authors; writing – original draft preparation, J.L.R.M; Writing – Review and Editing, J.L.R.M; F.M.O and D.L.A.J; Visualization, J.L.R.M; F.M.O and D.L.A.J; Supervision, A.R.M.F., J.L.A.G. All authors have read and agreed to the published version of the manuscript.

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