Various learning management systems (LMSs) are available to facilitate the development, management, and distribution of digital resources for both face-to-face and online instruction. In recent decades, these methods have shown potential for greater efficiency compared to traditional “chalk and talk” approaches. Additionally, they have paved the way for the establishment of ubiquitous learning environments, marking a new era in education. In a trend accelerated by the coronavirus disease 2019 pandemic, LMSs have been increasingly adopted to overcome the restrictions inherent to in-person education. In medical education, LMSs such as Moodle, Canvas, Blackboard Learn, and others have been introduced and used to support teaching, learning, and assessment activities. Of these, Moodle stands out as the most popular choice for many medical schools and institutions, primarily due to its flexibility, functionality, and user-friendliness. The learning environment is gradually transforming from traditional in-person teaching to a hybrid educational approach, driven by the need to fulfill diverse educational demands. Numerous research studies have examined the usability of Moodle in medical education, demonstrating its effectiveness in addressing challenges related to adaptive personalized learning, collaborative learning, blended learning, and more. Consequently, Moodle has emerged as a valuable solution for medical educators seeking a versatile and robust platform to enhance their teaching methodologies. The present review focuses on the practical utilization of Moodle in medical education and the advantages it offers to this field.

Keywords: Adaptive learning; Collaborative learning; Flexibility; Functionality; Learning management system

Introduction

Various learning management systems (LMSs) are available to facilitate the development, management, and distribution of digital resources for both face-to-face and online instruction [1]. In recent decades, these methods have shown potential for greater efficiency compared to traditional “chalk and talk” approaches [2]. Additionally, they have paved the way for the establishment of ubiquitous learning environments, marking a new era in education [3]. In a trend accelerated by the coronavirus disease 2019 (COVID-19) pandemic, LMSs have been increasingly adopted to overcome the restrictions inherent to in-person education [4-6]. In medical education, LMSs such as Moodle (named as a reference to “modular object-oriented dynamic learning environment”), Canvas, Blackboard Learn, and others have been introduced and used to support teaching, learning, and assessment activities [7-12]. Moodle has been reported to be the most popular choice for many medical schools and institutions due to its flexibility, func-
tionality, and user-friendliness [13-16]. The present review is focused on the practical utilization of Moodle in medical education and the advantages it offers to this field.

**Methods**

This review is centered on recent studies concerning the use of Moodle in academic settings. Because Moodle's evolving technical features have influenced educational strategy, we also meticulously examined specific Moodle functionalities. While our review adopted a comprehensive approach, covering the full scope of academic subjects and levels, we placed special emphasis on gathering evidence from medical institutions and hospitals. To identify pertinent articles, we examined keywords and themes in educational publications, such as PubMed and Google Scholar. We aimed to understand evolving trends, growing areas of interest, and the trajectory of research emphasis over the years.

**Schema of Moodle**

Moodle is an open-source LMS that is widely used in educational institutions and organizations around the world [17]. It was developed in 2002 by computer scientist Martin Dougiamas as a digital platform for the creation, delivery, and management of online courses and learning materials [18-20]. Since then, Moodle has undergone numerous transformations to enhance its features, user experience, and functionality. This journey has been marked by functional improvements and essential bug fixes, all tailored to meet the evolving needs of educational practice. As the demand for greater sophistication and conditionality increased, beginning with Moodle 2.0, features were introduced that allowed educators to set criteria for course completion, establish prerequisites, and restrict access to activities [21-26]. With the rise of mobile internet usage, Moodle also began to accommodate different screen sizes and prioritize mobile-friendliness by incorporating so-called bootstrap-based themes, starting with version 2.5 in 2013 [27-31]. In the most recent version, Moodle LMS 4, the platform has been further refined to facilitate more efficient collaborative learning experiences for educators and more intuitive coursework completion for learners, built on a foundation of user-friendly operability [32-34].

With Moodle, educators can create and customize courses, incorporating a variety of multimedia elements such as videos, audio files, and interactive quizzes [35,36]. The system offers a range of tools for course administration, including gradebooks, discussion forums, and assignment submission features [37].

A key aspect of Moodle is its flexibility and adaptability to different learning environments [16]. The software supports a wide range of pedagogical approaches, allowing instructors to design courses that best suit their teaching style and objectives. In addition, Moodle facilitates communication and collaboration among learners and instructors [38]. It offers many collaboration tools, such as messaging features, forums, and Wiki functionality, that promote interaction and knowledge sharing. As an open-source platform, Moodle benefits from a large, active community of developers and users who contribute to its ongoing development and improvement [18]. This community-driven approach fosters innovation and enables the sharing of resources, plugins, and best practices. Overall, Moodle serves as a full-featured LMS that empowers educators to create engaging online learning experiences and support effective teaching and learning.

**Features of Moodle**

Moodle offers a variety of features designed to facilitate effective instruction and engage students in the learning process (Fig. 1). The following sections detail several key features [39].

1. **Course creation and customization**

Using Moodle, educators may create and customize online courses according to their teaching objectives. They can organize course materials into sections, upload files, embed multimedia, and incorporate interactive activities. This functionality enables instructors to design engaging and interactive learning experiences.

2. **Discussion forums**

Moodle provides discussion forums in which students can communicate with their peers and instructors. These forums foster collaboration, critical thinking, and knowledge sharing among students. Instructors can moderate discussions, pose questions, and encourage active participation.
3. Assignments and assessments
Moodle includes a range of assignment and assessment features. Educators can create various types of assignments, such as essays, quizzes, and projects, and set deadlines for submission. Moodle also includes a gradebook and related tools to facilitate efficient grading and timely provision of feedback.

4. Online quizzes and exams
With Moodle, online quizzes and exams can be built from various question types, including multiple choice, short answer, and matching questions. Instructors can set time limits, randomize questions, and provide immediate feedback to students upon completion. This functionality supports self-assessment and knowledge retention.

5. Communication tools
Moodle includes messaging features, such as private messaging and forums, to facilitate student-instructor communication. This allows students to ask questions, seek clarification, and receive guidance outside of class hours. These tools promote a supportive learning environment and foster a sense of community.

6. Content restriction
Using Moodle, instructors may release course content gradually or sequentially. Students can therefore be guided through a structured learning path while accessing materials in a logical and organized manner. This feature is particularly useful for self-paced or module-based courses.

7. Multimedia integration
Moodle supports the integration of multimedia elements, such as videos, audio files, and interactive simulations. Instructors can enrich their course content with multimedia resources to enhance student engagement and accommodate different learning styles.

8. Mobile accessibility
Moodle is designed to be accessible on various devices, including smartphones and tablets. Its responsive design ensures that students can access course materials, participate in activities, and engage with their learning anytime and anywhere, providing flexibility and convenience. However, smartphone apps exhibit some limitations in operating functions for learning or teaching activities compared to the computer-based version of Moodle.

9. Progress tracking and analytics
Moodle provides tools for monitoring student progress, such as activity completion and course completion tracking. Instructors can monitor student engagement, identify areas of improvement, and provide personalized support as needed. Learning analytics features in Moodle also enable instructors to gain insights into student performance and behavior patterns. These features help create an interactive and dynamic learning environment, promote collaboration, and support student-centered learning approaches.

10. Integrations
Moodle is a flexible LMS crafted for seamless integration with numerous external applications and platforms. Its commitment to open design and modular focus have given rise to a plethora of plugins and integrated features.
Through its open application programming interfaces and services, Moodle offers integration opportunities with student information systems, content repositories, and various other tools [42-45].

**Practical applications of Moodle**

While an online LMS may not be considered a mandatory tool for medical education, demand for computer-assisted LMSs has been rising. Many educators have recognized the value of Moodle’s diverse features and have effectively incorporated them for specific purposes. During the COVID-19 pandemic era, educators in an ophthalmology residency program used online learning as a key teaching strategy [46]. Those authors reviewed several commercial and open-source LMS options, including Blackboard, Desire2Learn, Edmodo, ConnectEDU, Moodle, Sakai, edX, and ilios. Moodle was selected for implementation due to its cost-effectiveness, feature availability, and compatibility with existing technical infrastructure. The authors concluded that LMS implementation was successful in meeting the needs of faculty and residents. Researchers in a physiology course at the Faculty of Medicine of the University of Montenegro assessed the effect of e-learning on student success in mastering coursework [47]. The authors compared two groups of students: one group who attended the physiology course prior to the implementation of the Moodle platform and another group who attended the course after Moodle had been fully introduced. They concluded that attending face-to-face lectures was associated with better academic performance. However, the introduction of Moodle increased attendance at face-to-face lectures and improved formative and summative scores. This study demonstrated the benefits of blended learning with web-based course management systems like Moodle in medical education.

1. **Forum activities**

In the Moodle platform, educators can utilize discussion forums for regular dialogue with students [48]. Students can access course materials at their own pace, and the tracking feature of the LMS allows them to diagnose their learning needs. In the Medical School of Universidade Cidade de São Paulo, Brazil, the internship program consists of rotations in several medical specialties and is designed to provide students with practical experience in various healthcare settings. Due to the diverse locations of these settings and the need for effective communication and feedback between students and teaching staff, the Moodle environment was used to facilitate teacher-student communication through the posting of messages and pedagogical information [49]. Additionally, forums have allowed students to maintain much more direct contact when not in class and more easily collaborate on projects despite not being co-located [50,51].

2. **Assignment activities**

In Moodle, the assignment activity enables educators to collect digital content such as word processor files, spreadsheets, images, and other materials from students and provide grades and feedback. An assignment can be provided to students through various activity modules. In a university hospital, an assignment consisting of essay and quiz activities was provided to teach research ethics to clinical researchers, and the authors concluded that the program was feasible for this purpose [52]. Although a specific module such as an assignment activity can be used to build a course in Moodle, various activity modules or a combination of those activities can also be flexibly selected and applied, depending on the instructor’s intention and the educational conditions of the institution.

3. **Quiz activities**

One of the most frequently used and powerful activities in Moodle is the quiz functionality. This enables educators to generate quizzes containing various question types, such as multiple choice, matching, short answer, and numerical questions. Furthermore, educators can customize the quiz settings in Moodle to promote voluntary self-directed learning [53]. To do this, instructors can set pre-written remarks to appear in response to each presented answer in a quiz, providing the immediate delivery of various pieces of feedback about the student’s performance [54,55]. This simultaneous preset feedback can also be utilized as guidance for self-directed learning [19,53].

4. **Workshop activities**

Peer review is sometimes adopted as a teaching method to foster students’ thinking skills through the assessment of their classmates. The Moodle workshop activity for peer assessment has been used to support peer review in educa-
tion [56-59]. In Moodle, educators establish a multi-criteria assessment form, through which students may evaluate one or more of their peers’ submissions. In previous research, when the grades assigned by peers were compared with those by instructors, no significant difference was found; consequently, this reduced the workload on the educators as well [60]. This peer feedback activity could be incorporated into online courses to improve students’ evaluative judgment [61]. Additionally, it can assist students in improving cognitive schema and strengthen positive attitudes toward discussing and cooperating with peers [62].

5. Lesson activities
The lesson activity module in Moodle is relatively flexible, allowing for the delivery of content and/or practice activities to students, with a composition that can vary in complexity [63]. With this module, educators can choose to craft content pages or instructional activities that offer students multiple paths or options to explore. To boost engagement and comprehension, educators can incorporate diverse question types, including multiple choice, matching, and short answer questions. Based on the student’s selected answers and the educator’s lesson design, the learning journey may lead the student to the next page, to return to a previous page, or even to take a different route altogether. This adaptability in the learning process ensures a dynamic and personalized learning experience for each student [64].

6. Wiki activities
The Wiki activity module enables participants to contribute to and modify a collection of webpages [65]. Wikis can either be collaborative, meaning that anyone can edit them, or individual, where each user has a Wiki that only that person can edit. One notable characteristic of a Wiki is its capacity to maintain a record of versions of user-created documents [66]. Each contribution made by a user to a Wiki page generates a new version, which is then recorded. As a result, it becomes feasible to track edits, identify the differences between consecutive versions, and even restore previous iterations when needed [67,68]. The tracking capability in a Wiki can enhance the collaborative process, producing a more defined and accurate document focused on a specific topic [69]. In a neuroscience course designed for first-year medical students, a Wiki-based group project was incorporated to assist students in reviewing course content and establishing clinically meaningful connections [70]. A total of 205 master students at a medical school participated in a course that incorporated a flipped-classroom model. In the course of their learning through online and in-class activities, the students were divided into two groups. One group (n=85) completed a group assignment using an educational Wiki, while the other group (n=120) followed a conventional approach. The students in the Wiki group expressed higher satisfaction with the course. Furthermore, both the quantity and the quality of the group assignments among students in the Wiki group surpassed those in the non-Wiki group [71]. These findings confirm that the use of a Wiki-based group assignment effectively enhanced student learning outcomes. Hence, cooperative learning is thought to nurture students’ collaborative skills and potentially enhance cognitive outcomes and overall academic performance [72].

7. Survey activities
The survey activity module in Moodle enables educators to collect data from students, providing valuable insights about their classes and facilitating self-reflection on their teaching methods [73]. Educators can design various types of questionnaires in the survey activity module. This module is an extremely valuable tool for researchers and educators alike, as it facilitates investigation through the gathering of insights from students or participants in each course. The tool also empowers researchers and educators to analyze the collected data effectively.

Current trends in the use of Moodle
As continuous innovations in e-learning technologies point towards an educational revolution, facilitating individualized learning experiences and enriching learners’ interactions with others [74], Moodle is increasingly utilized as a platform for adaptive and collaborative learning [75]. In an innovative approach, the Internal Medicine Residency Program at the Cleveland Clinic assessed the medical knowledge of its residents before clinical rotations. Trainees were given access to an online, adaptive spaced-education module to augment their medical knowledge before embarking on demanding outpatient clinical rotations. The effectiveness of this approach was demonstrated [76]. In higher education, online collaborative learning has incor-
oporated a diverse set of tools, including various Moodle activities such as forums, Wikis, workshops, and assignments, to foster cooperative learning experiences [77,78]. During the COVID-19 pandemic, courses on the Moodle platform served as alternatives to in-person curricula for medical student education [79]. Driven by the pandemic, some universities in the United States have introduced multi-institutional online didactic programs that have transformed the conventional resident teaching model from isolated institutional knowledge hubs into a collective nationwide learning repository [80].

Blended learning that combines the Moodle platform with in-person traditional teaching has also shown a positive impact on students’ knowledge, attitudes, and practices [81]. In a study conducted at the Faculty of Medicine, University of Pristina, Kosovska Mitrovica, third-year medical students participated in an assessment of the effectiveness of problem-based learning (PBL) modules integrated into blended learning courses on medical statistics [82]. A blended learning course on medical statistics and informatics was structured on the Moodle platform and comprised 15 theoretical lecture classes, 30 practical exercise classes, and 15 other classes involving online readings or seminars. The presented PBL modules were readily applicable to existing medical statistics courses developed on the Moodle platform, allowing for seamless implementation and integration.

In a study evaluating hybrid teaching and assessment approaches in anatomy courses, the researchers contrasted student performance in both the theoretical and practical segments of two initial anatomy courses across three semesters [83]. During the spring 2019 term, students experienced traditional, face-to-face classroom instruction and examinations for both components. In contrast, the spring 2020 semester began with conventional face-to-face methods, but a swift conversion occurred mid-term to online instruction and examinations. This abrupt transition to a digital format corresponded with elevated average scores and reduced score variance in both theoretical and hands-on assessments. However, in the spring 2021 term, when a wholly online approach was implemented, the average scores dropped. The results of this study indicate that blended teaching approaches may be as effective as conventional in-person instruction. However, for optimal results, careful planning and preparation are crucial.

The unique benefits provided by online learning environments, which can be lacking in traditional in-person instruction, are anticipated to fuel the growing adoption of blended learning in real-life educational settings. Consequently, demand is rising for a well-designed and effective LMS to meet these evolving requirements, and Moodle has been demonstrated to effectively fulfill these needs.

Limitations of Moodle

Despite these promising findings, Moodle faces some unresolved issues. Firstly, the platform may pose challenges for technology-challenged educators due to its somewhat confusing interface [84]. Consequently, educators may require prior knowledge or experience to effectively build a course within Moodle. Secondly, despite Moodle being a free open-source learning platform, the installation and support process may not be as user-friendly as desired [85]. While some companies offer assistance to institutions or individuals in setting up and maintaining the Moodle platform, the technical specifications for installation are relatively rigid, and the process lacks user-friendliness and intuitiveness. Thirdly, concerns have been raised regarding security vulnerabilities such as SQL injection risks, which could potentially grant an attacker unauthorized access and control over a database server [86]. It is imperative to promptly address security issues to maximize the safety and reliability of the Moodle platform.

Conclusion

Among the wide array of LMS options in medical education, Moodle has emerged as a preferred choice based on its remarkable functionality and cost-effectiveness. Over time, the learning environment has undergone a gradual shift from traditional in-person teaching to a hybrid educational approach, both in response to challenges like the COVID-19 pandemic and to accommodate diverse educational requirements. Various research studies analyzing the usability of Moodle in medical education have demonstrated its effectiveness in addressing issues related to adaptive learning, collaborative learning, and blended learning, among others. As a result, Moodle has been shown to be a valuable solution for medical educators seeking a versatile and robust platform to enhance their teaching methodologies.
Article information

Conflicts of interest
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References
35. Hilar SP. Moodle 2.5 multimedia cookbook. Packt Publishing; 2013.


