Review article

KMJ

KOSIN MEDICAL JOURNAL

Do we need Moodle in medical education? A review of its impact and utility

Seri Jeong[1], Hyunyong Hwang[2]

[1]Department of Laboratory Medicine, Hallym University Kangnam Sacred Heart Hospital, Hallym University College of Medicine, Seoul, Korea
[2]Department of Laboratory Medicine, Kosin University Gospel Hospital, Kosin University College of Medicine, Busan, Korea

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.
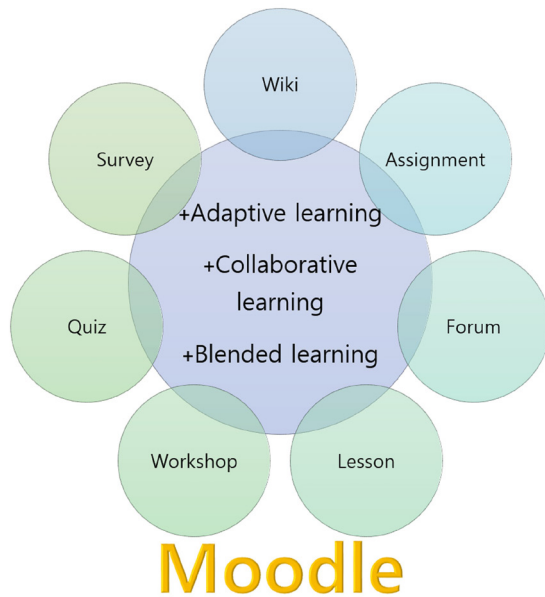
Features of Moodle

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.

Fig. 1. Key features of Moodle, showcasing its flexibility and adaptability to various learning environments. The Moodle platform offers a wide array of activities, including Wiki pages, assignments, forums, lessons, workshops, quizzes, surveys, and other features to meet the diverse needs of educators and to support various learning approaches, such as adaptive, collaborative, and blended learning.

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 [40]. 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 [41].

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 llios. 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 health-care 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-criterion 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-

porated 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

Funding

Author contributions

ORCID

Seri Jeong, https://orcid.org/0000-0002-4199-7033
Hyunyong Hwang, https://orcid.org/0000-0003-0662-3041

References

1. Gamage SH, Ayres JR, Behrend MB. A systematic review on trends in using Moodle for teaching and learning. Int J STEM Educ 2022;9:9.

2. Reis LO, Ikari O, Taha-Neto KA, Gugliotta A, Denardi F. Delivery of a urology online course using Moodle versus didactic lectures methods. Int J Med Inform 2015;84:149–54.

3. Aljawarneh SA. Reviewing and exploring innovative ubiquitous learning tools in higher education. J Comput High Educ 2020;32:57–73.

4. Tabatabai S. Simulations and virtual learning supporting clinical education during the COVID 19 pandemic. Adv Med Educ Pract 2020;11:513–6.

5. Lee SS, Lee H, Hwang H. New approach to learning medical procedures using a smartphone and the Moodle platform to facilitate assessments and written feedback. Kosin Med J 2022;37:75–82.

6. Kim S. Future directions of online learning environment design at medical schools: a transition towards a post-pandemic context. Kosin Med J 2023;38:12–20.

7. Xiao LL, Rahman SS. Predicting learning styles based on students' learning behaviour using correlation analysis. Curr Sci 2017;113:2090–6.

8. Shkoukani M. Explore the major characteristics of learning management systems and their impact on e-learning success. Int J Adv Comput Sci Appl 2019;10:296–301.

9. Alkhowailed MS, Rasheed Z, Shariq A, Elzainy A, El Sadik A, Alkhamiss A, et al. Digitalization plan in medical education during COVID-19 lockdown. Inform Med Unlocked 2020;20:100432.

10. Owolabi J, Bekele A. Implementation of innovative educational technologies in teaching of anatomy and basic medical sciences during the COVID-19 pandemic in a developing country: the COVID-19 silver lining? Adv Med Educ Pract 2021;12:619–25.

11. Waidyaratne GR, Kim S, Howell JD, Ike JD. Design, implementation, and reflections on a two-week virtual visual arts and medicine course for third- and fourth-year medical students. BMC Med Educ 2022;22:302.

12. Nikas IP, Lamnisos D, Meletiou-Mavrotheris M, Themistocleous SC, Pieridi C, Mytilinaios DG, et al. Shift to emergency remote preclinical medical education amidst the COVID-19 pandemic: a single-institution study. Anat Sci Educ 2022;15:27–41.

13. Memon AR, Rathore FA. Moodle and online learning in Pakistani Medical Universities: an opportunity worth exploring in higher education and research. J Pak Med Assoc 2018;68:1076–8.

14. Kakasevski G, Mihajlov M, Arsenovski S, Chungurski S. Evaluating usability in learning management system Moodle. In: 30th International Conference on Information Technology Interfaces; 2008 Jun 23-26; Cavtat, Croatia. IEEE; 2008. p. 613-8.

15. Morze N, Varchenko-Trotsenko L, Terletska T, Smyrnova-Trybulska E. Implementation of adaptive learning at higher education institutions by means of Moodle LMS. J Phys Conf Ser 2021;1840:012062.

16. Campo M, Amandi A, Biset JC. A software architecture perspective about Moodle flexibility for supporting empirical research of teaching theories. Educ Inf Technol (Dordr) 2021;26:817–42.

17. Hwang HY. The power of the quiz: the experience of a medical English class using Moodle. Korean J Med Educ 2009;21:53–8.

18. Dougiamas M, Taylor P. Moodle: using learning communities to create an open source course management system. In: EdMedia + Innovate Learning; 2003 Jun 23-29; Honolulu, USA. Association for the Advancement of Computing in Education (AACE); 2003. p. 171-8.

19. Hwang H. A computer-assisted, real-time feedback system for medical students as a tool for web-based learning. Kosin Med J 2016;31:134–45.

20. Costa C, Alvelos H, Teixeira L. The use of Moodle e-learning platform: a study in a Portuguese University. Procedia Technol 2012;5:334–43.

21. Alier M, Casan MJ, Piguillem J. Moodle 2.0: shifting from a learning toolkit to a open learning platform. In: TECH-EDUCATION 2010: Technology Enhanced Learning. Quality of Teaching and Educational Reform; 2010 May 19-21; Athens, Greece. Springer; 2010. p. 1–10.

22. Cooch M. Moodle 2.0 first look. Packt Publishing; 2010.

23. Muhsen ZF, Maaita A, Odah A, Nsour A. Moodle and e-learning tools. Int J Mod Educ Comput Sci 2013;5:1-8.

24. Conde MA, Gomez DA, Del Pozo A, Garcia FJ. Web services layer for Moodle 2.0: a new area of possibilities in web based learning. Int J Technol Enhanc Learn 2011;3:308–21.

25. Piguillem Poch J, Alier Forment M, Casany Guerrero MJ, Mayol Sarroca E, Galanis N, Garcia Penalvo FJ, et al. Moodbile: a Moodle web services extension for mobile applications. In: 1st Moodle Research Conference; 2012 Sep 14-15; Heraklion, Greece. 2012. p. 148–56.

26. Usagawa T, Nakashima Y, Chisaki Y, Nagai T, Kita T. An attendance management system for Moodle using student identification card and Android device. In: International Conference on Information, Communication Technology and System (ICTS); 2014 Sep 24; Surabaya, Indonesia. IEEE; 2014. p. 199-204.

27. Wogu I, Atayero A, Abolade A, Chidozie FC, Olu-Owolabi F, Godwyns A, et al. Using MOODLE 2.5 for E-evaluation and assignments for students learning at Covenant University. In: 6th International Conference on Education and New Learning Technologies; 2014 Jul 7-9; Barcelona, Spain. IATED; 2014. p. 4063-71.

28. Oliveira LCD, Cavalli VT, Dias AM, Oliveira MAD. Gamification for online training of court professionalsin a Labour Court in São Paulo, Brazil (TRT-2): what can be implemented in Moodle 2. 5. Eccos Revista Científica 2018;(46):171–90.

29. Zarubica M, Filipovic L, Terzic J, Milosavljevic L, Gazivoda V. Digitization and improvement of the distance learning platform at the University of Montenegro during the COVID-19 pandemic. ETF J Electr Eng 2021;27:12–9.

30. Jobe W. A Kenyan Cloud School: massive open online & ongoing courses for blended and lifelong learning. Open Praxis 2013;5:301–13.

31. Aberdour M. Moodle for mobile learning. Packt Publishing; 2013.

32. Buchner A. Moodle 4 Administration: an administrator's guide to configuring, securing, customizing, and extending Moodle. Packt Publishing; 2022.

33. Khairani NA, Rajagukguk J. Development of Moodle e-learning media in industrial revolution 4.0 era. In: Proceedings of the 4th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2019); 2019 Sep 23-24; Medan, Indonesia. Atlantis Press; 2019. p. 752-8.

34. Chen CJ, Tsai HJ, Lee MY, Chen YC, Huang SM. Effects of a Moodle-based E-learning environment on E-collaborative learning, perceived satisfaction, and study achievement among nursing students: a cross-sectional study. Nurse Educ Today 2023;130:105921.

35. Hilar SP. Moodle 2.5 multimedia cookbook. Packt Publishing; 2013.

36. Arianti BDD, Kholisho YN, Sujatmiko SB. The development of e-learning use MOODLE as a multimedia learning medium. J Phys Conf Ser 2020;1539:012033.

37. Kim E, Park H, Jang J. Development of a class model for improving creative collaboration based on the online learning system (Moodle) in Korea. J Open Innov Technol Mark Complex 2019;5:67.

38. Kumar V, Sharma D. Creating collaborative and convenient learning environment using cloud-based Moodle LMS: an instructor and administrator perspective. Int J Web-Based Learn Teach Technol 2016;11:35–50.

39. Athaya H, Nadir RDA, Indra Sensuse D, Kautsarina K, Suryono RR. Moodle implementation for e-learning: a systematic review. In: SIET '21: Proceedings of the 6th International Conference on Sustainable Information Engineering and Technology; 2021 Sep 13-14; Malang, Indonesia. Association for Computing Machinery; 2021. p. 106-12.

40. Peramunugamage A, Usoof H, Hapuarachchi J. Moodle mobile plugin for problem-based learning (PBL) in engineering education. In: 2019 IEEE Global Engineering Education Conference (EDUCON); 2019 Apr 8-11; Dubai, United Arab Emirates. IEEE; 2019. p. 827-35.

41. Papadakis S, Kalogiannakis M, Sifaki E, Vidakis N. Access Moodle using smart mobile phones: a case study in a Greek University. In: Interactivity, Game Creation, Design, Learning, and Innovation: 6th International Conference; 2017 Oct 30-31; Heraklion, Greece. Springer; 2018. p. 376-85.

42. Abu-Shawar B, Al-Sadi J, Hourani A. Integrating the learning management system with other online administrative systems at AOU. In: Proceedings of the 2006 International Conference on E-Learning, E-Business, Enterprise Information Systems, E-Government, & Outsourcing; 2006 Jun 26-29; Las Vegas, USA.

CSREA Press; 2006. p. 272-7.

43. Menemencioglua O, Sena B, Atasoya F, Sonuca E. LMS (Moodle) automatic enrollment approach by flat file with student information system data. Comput Sci 2012;1:314–9.

44. Mozelius P, Balasooriya I, Hettiarachchi E. eNOSHA and Moodle: the integration of two e-learning systems. In: Proceedings of the 10th European Conference on eLearning; 2011 Nov 10-11; Brighton, UK. Academic Publishing Limited; 2011. p. 509-16.

45. Rodrigues JRA, Brandao LO, Nascimento M, Rodrigues P, Brandao AA, Giroire H, et al. iQuiz: integrated assessment environment to improve Moodle quiz. In: 2013 IEEE Frontiers in Education Conference (FIE); 2013 Oct 23-26; Oklahoma City, USA. IEEE; 2013. p. 293-5.

46. Zainul R, Adri M, Sriadhi, Khaerudin, Wahyuningtyas N, Darni, et al. Development of e-learning courses for subjects about 'learn and learning' with Moodle-based for prospective teacher in Indonesia. J Phys Conf Ser 2020;1594:012023.

47. Popovic N, Popovic T, Rovcanin Dragovic I, Cmiljanic O. A Moodle-based blended learning solution for physiology education in Montenegro: a case study. Adv Physiol Educ 2018;42:111–7.

48. Amandu GM, Muliira JK, Fronda DC. Using Moodle e-learning platform to foster student self-directed learning: experiences with utilization of the software in undergraduate nursing courses in a Middle Eastern University. Procedia Soc Behav Sci 2013;93:677–83.

49. Lobach N, Isychko L, Dymar N, Vakaliuk I, Yuryk O, Bokova S. Moodle innovation learning technology for medical education: from theory to practice. J Pharm Res Int 2021;33(59A):245–60.

50. Marti E, Gurgui A, Gil D, Hernandez-Sabate A, Rocarias J, Poveda F. PBL on line: a proposal for the organization, part-time monitoring and assessment of PBL group activities. J Technol Sci Educ 2015;5:87–96.

51. Phungsuk R, Viriyavejakul C, Ratanaolarn T. Development of a problem-based learning model via a virtual learning environment. Kasetsart J Soc Sci 2017;38:297–306.

52. Halkoaho A, Matveinen M, Leinonen V, Luoto K, Keranen T. Education of research ethics for clinical investigators with Moodle tool. BMC Med Ethics 2013;14:53.

53. Oh CE, Hwang H. How does quiz activity affect summative assessment outcomes? An analysis of three consecutive years' data on self-directed learning. Kosin Med J 2022;37:228–35.

54. Gamage SH, Ayres JR, Behrend MB, Smith EJ. Optimising Moodle quizzes for online assessments. Int J STEM Educ 2019;6:27.

55. Manzan MCS, Dios MAQ, Sanchez RM, Llamazares MdCE, Gonzalez AA. Cuestionarios de e-autoevaluación y e-feedback: una aplicación en Moodle. Eur J Health Res 2018;4:135–48.

56. Hanh BM. What kind of changes we need in medical physiology education in developing countries-Vietnamese experiments. Korean J Physiol Pharm 2006;10:106.

57. Cox JM, Posada JP, Waldron R. Moodle workshop activities support peer review in year 1 science: present and future. In: 29th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education Conference; 2012 Nov 25-28; Wellington, New Zealand.

58. Li L, Tam CW, Wang N, Cheung F, Zhou Q, Zhang C, et al. Effectiveness of blending E-learning with field trip on Chinese herbal medicine education: quasi-experimental study. BMC Complement Med Ther 2020;20:248.

59. Dooley JF. Peer assessments using the Moodle workshop tool. In: ITiCSE '09: Proceedings of the 14th Annual ACM SIGCSE Conference on Innovation and Technology in Computer Science Education; 2009 Jul 6; Paris, France. Association for Computing Machinery; 2009. p. 344.

60. Guelfi MR, Formiconi AR, Vannucci M, Tofani L, Shtylla J, Masoni M. Application of peer review in a university course: are students good reviewers? J Elearn Knowl Soc 2021;17:1–8.

61. Lluch L, Cano E. How to embed SRL in online learning settings? Design through learning analytics and personalized learning design in Moodle. J New Approach Educ Res 2023;12:120–38.

62. Shen CH, Huang XY. The application of Moodle for web-based peer assessment. J Educ Media Libr Sci 2006;43:267–84.

63. Oliveira AC, Mattos S, Coimbra M. Development and assessment of an e-learning course on pediatric cardiology basics. JMIR Med Educ 2017;3:e10.

64. Ramos K, MacLean A, Bates P, Wylie P, Brempah A. Using Moodle lessons for the development of an e-learning programme in women's healh. In: E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education; 2010 Oct 18; Orlando, USA. Association for the Advancement of Computing in Education (AACE); 2013. https://www.learntechlib.org/primary/p/35642/

65. Rasmussen A, Lewis M, White J. The application of wiki technology in medical education. Med Teach 2013;35:109–14.

66. Garg A, Rajendran R. Investigating behavioral patterns of procrastinators in a Wiki-based activity. Educ Inf Technol (Dordr) 2023 May 16 [Epub]. https://doi.org/10.1007/s10639-023-11893-4

67. TretIn G. Using a wiki to evaluate individual contribution to a collaborative learning project. J Comput Assist Learn 2009;25:43–55.

68. Balderas A, Palomo-Duarte M, Dodero JM, Ibarra-Saiz MS,

Rodriguez-Gomez G. Scalable authentic assessment of collaborative work assignments in wikis. Int J Educ Technol High Educ 2018;15:40.

69. Alier M, Casany MJ, Piguillem J, Lapuente R. Creating wiki communities in blended learning environment and the creation of the Moodle New Wiki. Int J Soc Humanist Comput 2010;1:300–13.

70. Mi M, Gould D. Wiki technology enhanced group project to promote active learning in a neuroscience course for first-year medical students: an exploratory study. Med Ref Serv Q 2014;33:125–35.

71. Khoynaroud AA, Akbarzadeh A, Ghojazadeh M, Ghaffarifar S. Assessment of the effect of application of an educational wiki in flipped classroom on students' achievement and satisfaction. BMC Med Educ 2020;20:293.

72. Sampaio-Maia B, Maia JS, Leitao S, Amaral M, Vieira-Marques P. Wiki as a tool for microbiology teaching, learning and assessment. Eur J Dent Educ 2014;18:91–7.

73. Ismatovna AY. Moodle: as an effective learning management system in the modern digital world. Int J Incl Sustain Educ 2023;2:37–51.

74. Trukhacheva N, Pupyrev N. Blended-learning strategy in the Altay State medical university. Stud Health Technol Inform 2012;174:72–5.

75. Trukhacheva N, Tchernysheva S, Krjaklina T. The impact of e-learning on medical education in Russia. Elearn Digit Media 2011;8:31–5.

76. Brateanu A, Strang TM, Garber A, Mani S, Spencer A, Spevak B, et al. Using an adaptive, self-directed web-based learning module to enhance residents' medical knowledge prior to a new clinical rotation. Med Sci Educ 2019;29:779–86.

77. Dahal N. Understanding and uses of collaborative tools for online courses in higher education. Adv Mob Learn Educ Res 2022;2:435–42.

78. ArchMiller A, Fieberg J, Walker JD, Holm N. Group peer assessment for summative evaluation in a graduate-level statistics course for ecologists. Assess Eval High Educ 2017;42:1208–20.

79. Ettl F, Schriefl C, Grafeneder J, Thallner DG, Mueller M, Fischer E, et al. A Moodle course to substitute resuscitation teaching in a medical curriculum during the COVID-19 pandemic: a prospective pilot study. Front Public Health 2022;10:991408.

80. Li Y, Kern NG, Conti SL, Hampson LA. Online collaborative learning in urology. Curr Urol Rep 2021;22:66.

81. Luo L, Cheng X, Wang S, Zhang J, Zhu W, Yang J, et al. Blended learning with Moodle in medical statistics: an assessment of knowledge, attitudes and practices relating to e-learning. BMC Med Educ 2017;17:170.

82. Bukumiric Z, Ilic A, Pajcin M, Srebro D, Milicevic S, Spaic D, et al. Effects of problem-based learning modules within blended learning courses in medical statistics: a randomized controlled pilot study. PLoS One 2022;17:e0263015.

83. Albalushi H, Al Mushaiqri M, Sirasanagandla SR, Das S. Students' performance in face-to-face, online, and hybrid methods of teaching and assessment in anatomy. Int J Environ Res Public Health 2022;19:13318.

84. Bower M, Wittmann M. A comparison of lams and Moodle as learning design technologies: teacher education students' perspective. Teach Engl Technol 2011;11:62–80.

85. Al-Ajlan A, Zedan H. E-learning (Moodle) based on service oriented architecture. In: EADTU's 20th Anniversary Conference; 2007 Nov 8-9; Lisbona, Portogallo.

86. Kumar S, Dutta K. Investigation on security in LMS Moodle. Int J Inf Technol Knowl Manag 2011;4:233–8.