New Orleans JAZZED about Engineering Education

Paper ID #14949

State-of-the-Art-Matrix Analysis for Usability of Learning Management Systems

Dr. Burchan Aydin, Texas A&M University - Commerce

Burchan Aydin is an Assistant Professor of Engineering and Technology at Texas A&M University-Commerce. He received his Ph.D. in Industrial Engineering from Texas Tech University, Lubbock, TX, MAA from the University of the Incarnate Word, San Antonio, TX, and BS of Industrial Engineering degree from the Middle East Technical University, Ankara, Turkey. His major interest areas include software usability, user centered design, human factors, performance measurement, sustainability, and technology management.

Dr. Muge Mukaddes Darwish, Texas Tech University

Muge Mukaddes Darwish received her Ph.D. in interdisciplinary engineering and master's of science from Texas Tech University in 1998 and 1991 respectively. She received her graduate diploma in Bari Italy in 1982. She received her bachelor's of science and advance engineering degree in 1978 Ataturk University in Turkey. She worked as Chief Engineer for the Minister of Agriculture and Urban Development from 1978 to 1981. She is currently Associate Professor at Texas Tech University in the Construction Engineering & Engineering Technology Department.

Dr. Emre Selvi, Jacksonville University

Emre Selvi is an Assistant Professor of Mechanical Engineering at Jacksonville University. He received his B.S. and M.S. from Middle East Technical University and Ph.D. from Texas Tech University. He worked as a Design and Production Engineer for Aselsan Inc. for four years and as a Faculty at Muskingum University for six years. His research interests are high pressure material science and engineering design, especially as it relate to educational environments.

THE STATE-OF-THE-ART MATRIX ANALYSIS FOR USABILITY OF LEARNING MANAGEMENT SYSTEMS

Abstract

This is a research study to explore trends, gaps, and issues in the literature of the usability of Learning Management Systems (LMS). The authors utilized the State-of-the-Art Matrix analysis, which is a research method that has been used extensively in the last decade. It is a systematic evaluation of existing research by using several statistical methods. Pareto analysis and Histograms are part of this analysis. The analysis revealed several gaps: (1) engineering students have not been the main focus of research in any studies, (2) there is no research that compares usability of LMS between different academic disciplines, (3) there is no modeling effort for understanding if engineering students and instructors need different LMS design than other disciplines, (4) primary framework development for evaluating LMS has declined, (5) discount usability methods (heuristics) have been mostly preferred for the evaluation of LMS ignoring effectiveness and efficiency performance measures related to LMS usage, (6) there are very limited studies incorporating usability design with instructional and accessibility design, (7) there are very limited studies investigating LMS usability with regards to occupational training, (8) there are many researchers who mentioned the significance of research on usability of mobile e-learning platforms. The results of this study established a basis for future work and the authors will study LMS usability for engineering students and instructors by future empirical studies.

Introduction

E-learning provides education opportunities by eliminating geographical and time constraints[55]; it also offers decongestion of overcrowded education facilities[7]. It's a way to establish distance education by distributing learning material and processes by utilizing the attributes and the resources of the World Wide Web[66]. According to the statistics from the Institute of Education Sciences, more than 27% of students in US during 2013 took distance education courses.

An LMS is a software tool that is designed to facilitate e-learning[33]. It embraces services needed for handling online teaching activities[19]. It is the "infrastructure that delivers and manages the instructional content, identifies and assesses individual and organizational learning or goals, tracks the progress towards the goals, collects and presents data for managing the learning process of an organization" [90].

In the field of e-learning, LMSs are also called Virtual Learning Environments (VLE), Course Management Systems (CMS)[50], online learning portals[33], or learning content management systems (LCMS)[63]. LMS have become the main focus of e-learning research[21] since academic institutions rely heavily on LMS technology to assist in course delivery[70]. Various LMS have been designed in the last decade by considering the instructional/pedagogical and human-computer interaction design concepts. The focus of this paper is an important design concept in human-computer interaction; 'usability'.

Usability is defined in ISO 9241-11 guidelines as ―the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a

specified context of use[38]. It is a measure of how well software facilitates user learning, helps users remember what they have learned, reduces error rates, increases efficiency and effectiveness, and how much users are satisfied with the software[22]. Usability of LMS can directly affect the acceptance and success of e-learning[33]. Ease-of-use of LMS is a key factor in adaptation of the students and the instructors to this technology[70]. In a study conducted by Tselios *et al*. (2001), significant positive correlation between usability of an LMS and student performance was found[84]. Ardito *et al.*, (2006) discussed that students should concentrate on learning the educational material rather than trying to learn how to use the LMS[7,8]. Moreover, Tee *et al.* (2013) addressed the importance of usability as part of an effective learning process in e-learning applications[81]. Furthermore, Triacca *et al.* (2004) mentioned the necessity of usability for effective online environments and applications[84]. It is assured that an LMS with low level of usability will not enable users to access and assimilate information at all[55]. Thus, usability should be accounted as a significant factor for effective design of LMS. Unfortunately, even though a large number of organizations have adopted e-learning programs, few of those have addressed the usability of LMS[55,71]. The LMS usability concept is more challenging than basic website usability[51]. The reason is that it is about ensuring that a highly flexible system offers high level of customization options at every level (platform, course, user generated contents), and integrates components added by different sources (developers, administrators, instructors, students) for various objectives[51].

Considering the continuous evolution of e-learning and importance of the usability of course delivery systems in the success of e-learning, this paper presents a comprehensive literature research on the domain of "the usability of LMS". There have been limited literature research publications in this domain[24, 25, 26, 35, 40, 55, 79, 91], and none of these have provided any quantitative analysis. Thus, the main purpose of this study is to determine the major issues and gaps in the usability of LMS research by using a systematic literature research method that includes quantitative analysis.

The specific research questions that this study addresses are as follows:

1. What are the trends for framework development for usability evaluation of LMS?
2. Which usability evaluation methods are utilized for the evaluation of LMS in the literature?
3. Have researchers covered all user population of the LMS or have focused particularly on a certain group?
4. Which LMS types have been investigated most frequently?
5. What are the key areas researchers have emphasized so far? What are the gaps in the literature?

The method used to address these research questions is the State-of-the-Art Matrix (SAM) analysis.

Methodology

The SAM analysis method was developed by Beruvides and Omachonu (2001). It's defined as "a research mining methodology to develop matrices to partition research information to isolate critical information using statistical methods"[11]. The method proposes dividing the literature into classifications such as primary theory, secondary theory, empirical studies, case studies. Another approach is analyzing time trends to detect the progress of research, and additionally

keywords are collected from the literature to specify principal terms in the subject area[11]. The SAM for usability of LMS focused on the engineering education, e-learning, human factors, and LMS design research subject areas. The literature was collected through various academic and professional online research databases such as library catalogs provided by authors' universities, IEEE Xplore , EBSCOhost, Google Scholar and other various tools. The main keywords used in the search queries can be listed as, but not limited to; 'LMS usability', 'usability evaluation of LMS', 'evaluation of LMS', and 'usability evaluation framework for LMS'. From a total of 126 papers collected, 82 were selected for the SAM analysis considering the relevance to LMS usability subject. The time range is from 1995 to present day.

The categories for the SAM in this study are determined as follows. Previous studies that used the SAM were analyzed[9, 11, 15, 64, 80, 83]. It's detected that there is not a definite set of categories to be followed. The literature can be classified into case-specific categories. In this case, the literature included papers that: (1) Evaluate the usability of an LMS, (2) compare the usability of multiple LMSs, (3) propose a framework to evaluate any LMS, (4) modify or extend previously developed framework, (5) review the literature of usability of LMS, and (6) provide insights/perspectives on usability of LMS. Therefore, the literature was divided into six main categories. The following are the operational definitions for these categories.

Table 1: Operational Definitions for the Categories of the State of the Art Matrix Analysis.

Category	Operational Definition
Primary Framework	A set of guidelines, standards established for evaluating the usability of an LMS. It can also be a collection of pre-developed guidelines, heuristics and models converted into a framework.
Secondary Framework	Modified or extended version of a primary framework.
Literature Review	Collection of research that have been performed on usability of LMS.
Opinion Based	A study that includes solely discussion of ideas on usability of LMS.
Empirical Study	A usability study that includes real users (subjects).
Analytical Study	A usability study that requires expert evaluation where experts put themselves in the position of users and evaluate the system.

It should be noted that a paper can be listed under multiple categories. After the papers are categorized, the next step is a detailed analysis to detect the gaps in the literature. Pareto Analysis and Histograms are the statistical tools that were employed for this step. Afterwards, keywords are collected from the studies to discover the focus of researchers. This step is useful to establish the interest of researchers so far. It is a simple and effective way of discovering gaps in the research domain. Furthermore, the primary and the secondary framework classification types were sorted according to the year they were published in order to analyze time trends in the research. The next section demonstrates the SAM matrix, and the results of the analysis.

Results

Table 2 represents the SAM matrix for usability of LMS. Studies are coded by the reference list numbers.

Table 2: The SAM Matrix.

Category	Reference Number
Primary Frameworks	1, 4, 6, 7, 17, 18, 19, 24, 25, 27, 28, 30, 34, 45, 51, 52, 56, 57, 59, 60, 66, 67, 69, 74, 76, 84, 92, 93
Secondary Frameworks	8, 20, 21, 37, 42, 61, 62
Literature Review	24, 25, 26, 35, 40, 55, 79, 91
Opinion Based	None
Empirical Usability Study	1, 2, 3, 6, 7, 8, 10, 12, 13, 14, 16, 17, 21, 23, 27, 29, 30, 31, 33, 34, 36, 39, 41, 42, 43, 44, 46, 47, 48, 49, 50, 54, 56, 59, 62, 66, 67, 68, 70, 72, 73, 76, 77, 78, 81, 82, 85, 86, 87, 88, 89, 91, 92, 93
Analytical Usability Study	4, 5, 6, 7, 29, 32, 34, 37, 41, 45, 51, 52, 53, 57, 60, 63, 65, 69, 71, 72, 73, 77, 84

Empirical usability evaluation studies were further sorted into ‘questionnaire’ and ‘usability testing’ sub-categories. Moreover, the analytical usability evaluation studies were divided into ‘heuristics’ and ‘design guidelines’ sub-categories. Although there are many other empirical and analytical usability evaluation methods, only these sub-categories were detected in the usability of LMS literature.

The first two categories (primary and secondary frameworks) were analyzed separate from other categories to find out a trend on framework development for usability evaluation of LMS. Figure-1 shows primary framework development trend from 1995 to present.

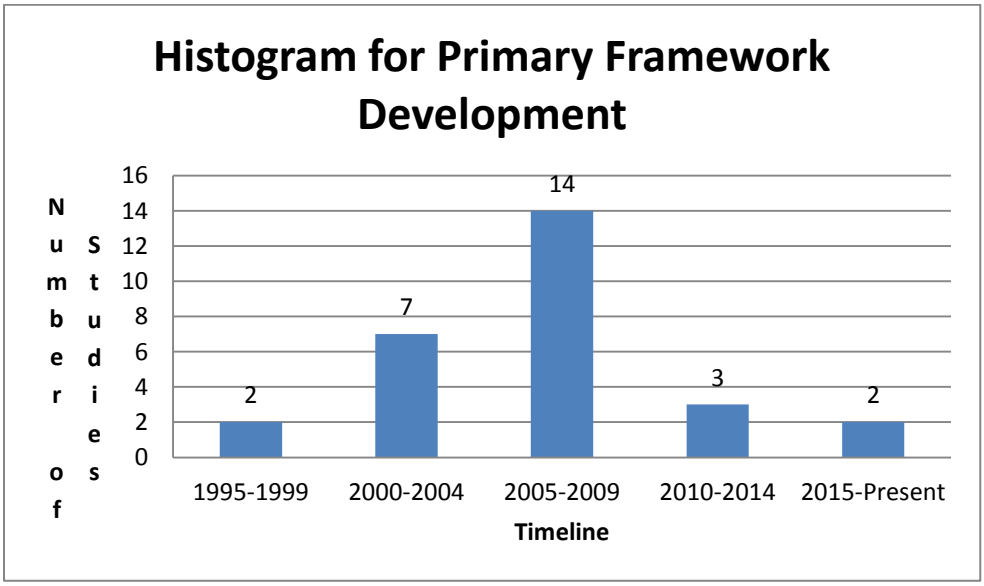

Figure 1: Trends for Primary Framework Development.

The histogram indicates that more than 80% of primary framework development has been performed before 2010. There is a very limited primary framework development effort in the last five years. It is also important to investigate the trends for secondary framework development. Figure-2 shows a histogram for secondary framework development for usability evaluation of LMS.

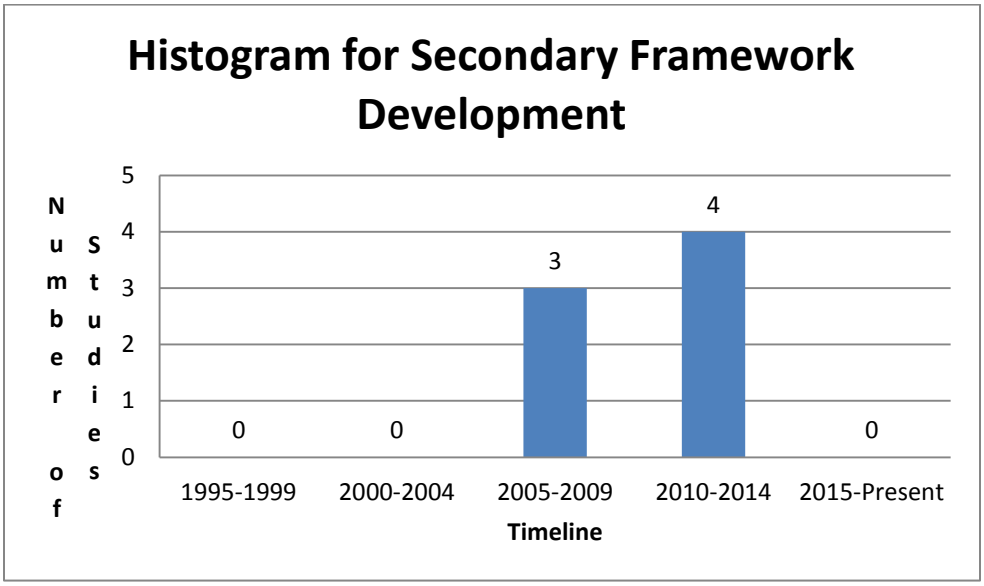

Figure 2: Trends for Secondary Framework Development.

It is clear from Figure 2 that there have been several secondary framework development efforts from 2005 until 2014. No study has been published since 2014 that shows a modification or extension of primary frameworks.

The next step in the SAM analysis was to determine which usability evaluation methods have been dominantly used or recommended. The questionnaire, the usability testing, the heuristics, and the design guidelines categories of the SAM matrix were analyzed by Pareto analysis. A Pareto chart is a tool to graphically summarize and display the relative importance of the differences between groups of data[75]. The left-side vertical axis of the Pareto chart is labeled as frequency (the number of counts for each category), the right-side vertical axis of the Pareto chart is the cumulative percentage, and the horizontal axis of the Pareto chart is labeled with the group names of the response variables. The groups are ordered in descending frequency magnitude[75]. The 80/20 Pareto rule indicates that 20% of groups have the 80% overall impact. Table 3 shows the number of times each method was used.

Table 3: Usability Evaluation Methods used for LMS Evaluation in the Literature.

Usability Evaluation Method	Frequency	Cumulative Number	Cumulative %
Questionnaire	46	46	51
Heuristics	22	68	75
Usability Testing	21	89	99
Design Guidelines	1	90	1

Multiple methods are used or recommended in some papers, therefore, the total number in Table 3 is larger than the total count of 82 papers in the SAM analysis. According to the Pareto rule, it can be concluded that questionnaire and heuristics are the two main methods that are used or recommended in the usability of LMS literature. Figure 3 demonstrates the associated Pareto chart.

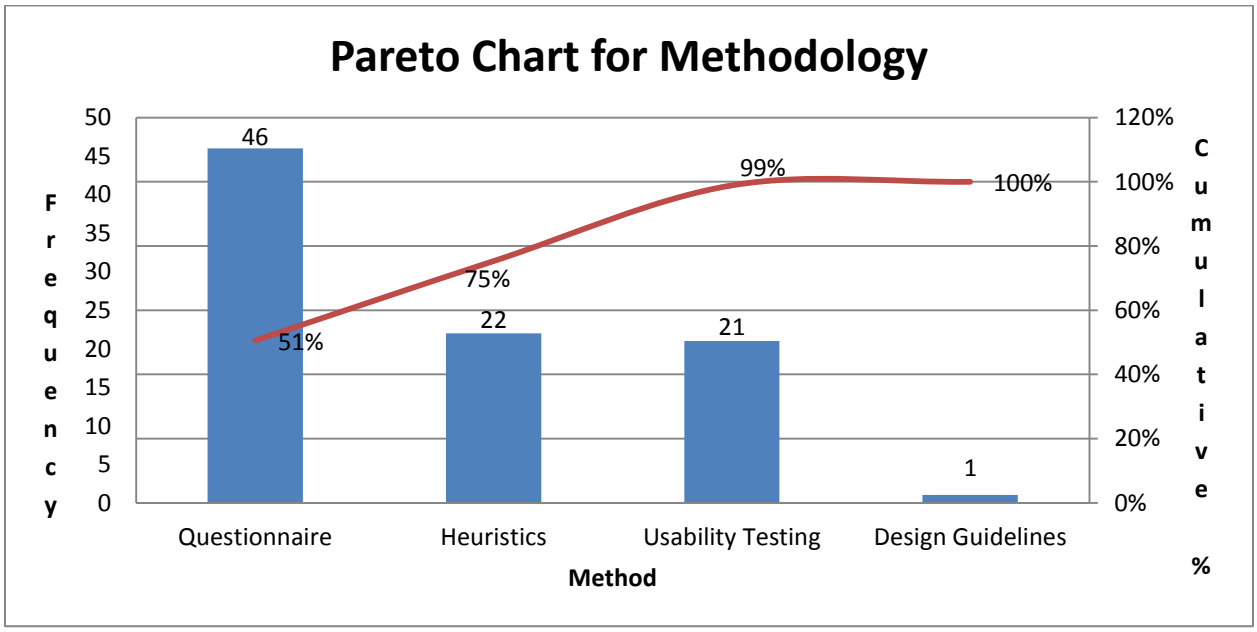

Figure 3: Pareto Chart for Usability Evaluation Methods.

The figure also shows that empirical usability evaluation methods (in this case questionnaires and usability testing) were used or recommended more than the analytical usability evaluation methods (in this case, heuristics and design guidelines). Empirical usability evaluation methods were used or recommended in 54 papers to evaluate LMS; whereas analytical usability evaluation methods were used or recommended in 22 studies. In only 8 papers, empirical and analytical methods were used or recommended cooperatively with three options listed as follows:

(1) Questionnaires supplemented with Heuristics.
(2) Usability testing supplemented with Heuristics.
(3) Questionnaire and usability testing supplemented with Heuristics.

The following figure is a simple representation of the number of papers that use or recommend empirical and analytical methods.

Figure 4: Empirical vs. Analytical Usability Evaluation Methods.

The next analysis is the comparison of the participant types in the usability evaluation studies for LMS. There are four types of subjects that participated in these studies; (1) students, (2) instructors, (3) administrators, and (4) occupational subjects. The Pareto analysis was employed to determine the dominant participant type. Figure-5 is the Pareto chart for participant types in usability evaluation of LMS studies. The 80/20 Pareto rule indicates that students have been the major participants in these studies since it is the only group inside the 80% range. However, there are very limited studies that used engineering students or instructors as subjects.

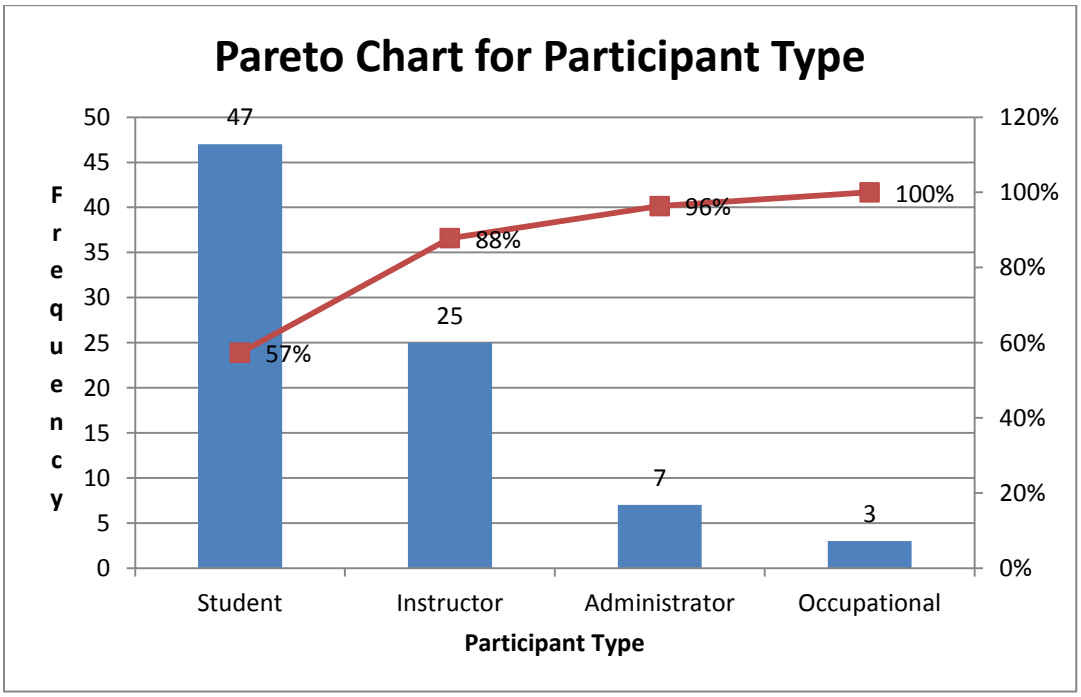

Figure 5: Pareto Chart for Participants.

The next analysis was conducted to determine the major LMS types evaluated by the researchers. It should be noted that there are enormous variety of LMS options for e-learning. The authors established the LMS type categories as 'Moodle' (an open source system), 'Blackboard' (proprietary system), 'others', and 'own LMS'. The latter category was established to account for the studies that actually proposed a new LMS. LMS types that had two or less repetitions in the SAM Matrix were collected under the same category called 'others'. The 'others' category contains a total of 38 different types of LMSs. Figure 6 shows the Pareto chart that illustrates the usage rates of LMS types in the literature.

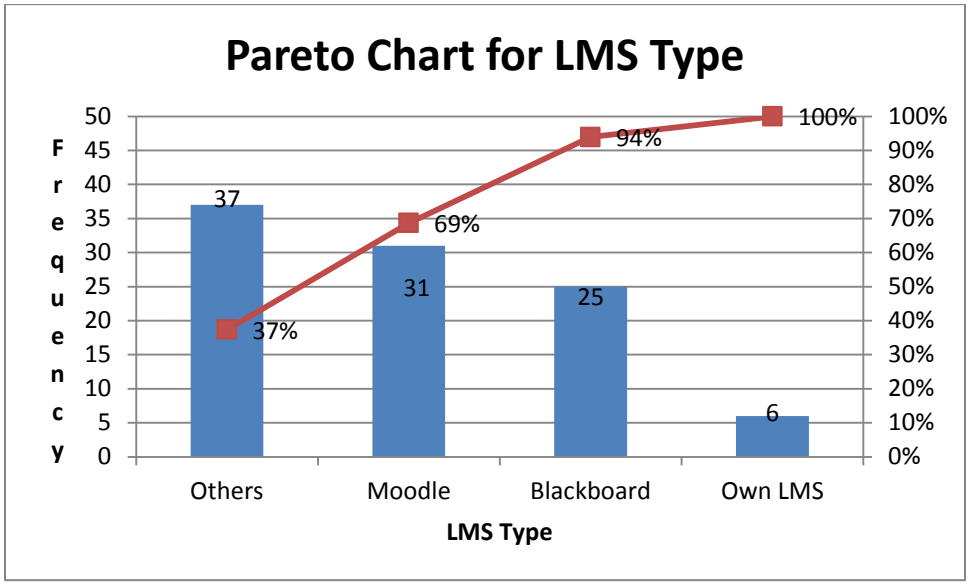

Figure 6: Pareto Chart for LMS Type.

It can be deduced from the figure that Moodle has been the most emphasized LMS in the literature of usability of LMS. Although Blackboard is not in the 80% cumulative range, it is the second most focused LMS in the literature. Populating all other types of LMS' under one category caused Blackboard to move out of the 80% region of the Pareto chart.

The final analysis was to collect the keywords listed in each study. Only 48 out of 82 studies listed keywords. E-learning, usability evaluation, LMS, Moodle, Blackboard, and Human Factors were the keywords that were used frequently. Only a few studies focused also on pedagogical design and accessibility of LMS.

Discussions

The SAM revealed several gaps and challenges in the usability of LMS literature. The following research questions were addressed.

1. What are the trends in framework development for usability evaluation of LMS?

The Development of frameworks for the usability evaluation of LMS has been declining. The effort currently is on modifying or extending the existing primary frameworks into secondary frameworks. The majority of these frameworks covered only the usability guidelines yet ignored

the pedagogy and accessibility design guidelines. There are limited studies that usability and pedagogical design concepts had been introduced into the framework. However, a framework that takes all three concepts into consideration has not been found in the literature. A promising future study might be establishing a framework that combines usability, pedagogy, and accessibility design with respect to LMS development. Moreover, majority of these frameworks do not incorporate usability testing, rather uses heuristics and design guidelines. Usability testing is not a discount usability method; it requires more time and budget. Incorporating usability testing into the framework would help measuring efficiency and effectivess.

2. Which usability evaluation methods are utilized for the evaluation of LMS in the literature?

Questionnaires are the mostly used evaluation method in the usability of LMS literature. The measures evaluated via questionnaires are mainly user satisfaction from different modules of the LMS, and the users' preferences. There is immediate need for further research studies to conduct usability testing in order to evaluate objective measures related to LMS performance. Effectiveness and efficiency of LMS shall be evaluated via usability testing. There are several studies that usability testing was performed, but it is not clear whether the latest version of the LMS were evaluated. There are regular updates on LMS software. New versions are released frequently. These studies should be repeated for the latest versions of the associated LMSs.

3. Have researchers covered all user population of the LMS or have focused particularly on a certain group?

Students have been the main focus of usability for LMS research. Further research must focus on the other portions of the user population; the instructors and the administrators. We believe that the usability of LMS from the perspectives of instructors and administrators are also important. Moreover, the number of studies that focus on engineering students and instructors are very limited. Less than 10% of the studies involved engineering students or faculty as participants. Walker *et al.* (2013) evaluated the user experience in Moodle in an Art& Design institution, and suggested that there may be variability of user experience in different academic disciplines. The reason is that every academic discipline has different requirements and demands[89]. Further study shall emphasize usability of LMS with respect to engineering students and instructors. This research endeavor might as well lead to model the relationship between the usability of LMS for engineering vs. other academic disciplines. It has been detected from the SAM that there are not sufficient research endeavors to understand how usable LMS are with respect to occupational training in corporations. The research has been focusing on usability of LMS in educational institutions, yet corporation e-training has been disregarded. The authors are planning to focus on LMS usability for different types of employees; covering blue collar and white collar employees' trainings.

4. Which LMS types have been investigated mostly?

Moodle and Blackboard have been the mostly used LMS in the usability of LMS literature. There are studies that developed a framework and tested it for the evaluation of these two LMS types. Also, there are studies that compared the usability of these two LMS without developing a

framework. These studies detected several usability problems in both LMS. Further study shall investigate if these usability problems were tackled in the latest versions of Moodle and Blackboard.

5. What are the key areas researchers have emphasized so far? What are the gaps in the literature?

The keyword analysis showed that researchers mentioned the need for a research emphasize on mobile e-learning. Further SAM analysis can be performed on the research subject of mobile e-learning. The keyword analysis also supported our discussion of the lack of framework that is comprehensively covering usability, pedagogy, and accessibility.

Conclusion

The main objective of this study was to detect the gaps in the usability of LMS literature. The SAM analysis has been extensively used in the last decade. It is a research method that statistically proves the trends and the gaps. The authors believe that the most promising ones are (1) the need for a novel LMS evaluation framework that incorporates empirical and analytical usability evaluation methods and combines usability design, pedagogical design, and accessibility, and (2) a need for modeling the usability of LMS to compare engineering users vs. other academic disciplines' users to see if engineering e-learning needs any different approach on LMS design. The results of this study established a basis for future work to improve engineering e-learning. The authors will study LMS usability for engineering students and instructors by future empirical studies.

Bibliography

1. Abante, M. V., Rabago, L. W., & Tanguilig III, B. T. (2015). An Evaluation of Integrated Dynamic Learning Environment (IDLE) at College of Saint John Paul II Arts and Sciences on ISO-9126. *In Proceedings of the Second* International Conference on Electrical, Electronics, Computer Engineering, and their Applications (EECEA2015), pp. 63-70.

2. Al-Khalifa, H. S. (2010). A first step in evaluating the usability of Jusur learning management system. In *The 3rd Annual Forum on e-Learning Excellence in the Middle East*.

3. Al-sarrayrih, H. S., Knipping, L., & Zorn, E. (2010). Evaluation of a Moodle based learning management system applied at berlin institute of technology based on iso-9126. In *Proceedings of ICL 2010 Conference Hasselt Belgium* (pp. 880-887).

4. Albion, P. (1999). Heuristic evaluation of educational multimedia: from theory to practice. In *Proceedings ASCILITE 1999: 16th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Responding to Diversity* (pp. 9-15). Australasian Society for Computers in Learning in Tertiary Education (ASCILITE).

5. Almarashdeh, I. A., Sahari, N., Zin, M., & Azan, N. (2011, July). Heuristic evaluation of distance learning management system interface. In *Electrical Engineering and Informatics (ICEEI), 2011 International Conference on* (pp. 1-6). IEEE.

6. Alsumait, A., & Al-Osaimi, A. (2009, December). Usability heuristics evaluation for child e-learning applications. In *Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services* (pp. 425-430). ACM.

7. Ardito, C., Costabile, M. F., De Angeli, A., & Lanzilotti, R. (2006, October). Systematic evaluation of e-learning systems: an experimental validation. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles* (pp. 195-202). ACM.

8. Ardito, C., Costabile, M. F., De Marsico, M., Lanzilotti, R., Levialdi, S., Roselli, T., & Rossano, V. (2006). An approach to usability evaluation of e-learning applications. *Universal access in the information society*, *4*(3), 270-283.

9. Aydin, B., Millet, B., & Beruvides, M. G. (2011). The State-of-the-Art Matrix Analysis for Cost-Justification of Usability Research. ASEM Annual Conference Proceedings, CD-ROM Lubbock, TX, 9p.

10. Baytiyeh, H. (2011, October). Work in progress—Open source usability evaluation: The case of Moodle. In *Frontiers in Education Conference (FIE), 2011* (pp. F4E-1). IEEE.

11. Beruvides, M. G., & Omachonu, V. (2001). A Systemic-Statistical Approach for Managing Research Information: The State-of-the-Art-Matrix Analysis. Industrial Engineering Research Conference Proceedings, CD-ROM, Dallas, Texas, 2001, 6p.

12. Blecken, A., Brüggemann, D., & Marx, W. (2010, January). Usability evaluation of a learning management system. In *System Sciences (HICSS), 2010 43rd Hawaii International Conference on* (pp. 1-9). IEEE.

13. Bos, B., Munoz, K. D., & Van Duzer, J. (2005). BlackBoard vs. Moodle: A Comparison of Satisfaction with Online Teaching and Learning Tools. *Humboldt State University. Retrieved March*, *7*, 2008.

14. Bremer, D., & Bryant, R. (2005, July). A Comparison of two learning management Systems: Moodle vs Blackboard. In *Proceedings of the 18th Annual Conference of the National Advisory Committee on Computing Qualifications* (pp. 135-139).

15. Calvo-Amodio, J., Palenke, H., & Beruvides, M. G. (2009). State of the Art Matrix of the Single Walled Nanotubes: An Evaluation of the Maturity of the Science. ASEM Annual Conference Proceedings, CD-ROM, Springfield, MO., 11p.

16. Chalk, P. D. (2002). Evaluating the use of a virtual learning environment for teaching aspects of HCI. In *ACM SIGCSE Bulletin* (Vol. 34, No. 3, pp. 125-129). ACM.

17. Chiu, C. M., Hsu, M. H., Sun, S. Y., Lin, T. C., & Sun, P. C. (2005). Usability, quality, value and e-learning continuance decisions. *Computers & Education*, *45*(4), 399-416.

18. Chua, B. B., & Dyson, L. E. (2004, December). Applying the ISO 9126 model to the evaluation of an e-learning system. In *Proc. of ASCILITE* (pp. 5-8).

19. Colace, F., De Santo, M., & Vento, M. (2003, January). Evaluating on-line learning platforms: a case study. In *System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on* (pp. 9-pp). IEEE.

20. Costabile, M. F., De Marsico, M., Lanzilotti, R., Plantamura, V. L., & Roselli, T. (2005, January). On the usability evaluation of e-learning applications. In *System Sciences, 2005. HICSS'05. Proceedings of the 38th Annual Hawaii International Conference on* (pp. 6b-6b). IEEE.

21. Daneshmandnia, A. (2013). A usability study of Moodle. *In Proceedings of the Spring 2013 Mid-Atlantic Section Conference of the American Society of Engineering Education*.

22. Donahue, G. M., Weinschenk, S., & Nowicki, J. (1999). Usability is Good Business. *IEEE Software*, *18*(1), 31-37.

23. Downey, S., Wentling, R. M., Wentling, T., & Wadsworth, A. (2005). The relationship between national culture and the usability of an e-learning system. *Human Resource Development International*, *8*(1), 47-64.

24. Dringus, L. (1995). An iterative usability evaluation procedure for interactive online courses. *Journal of interactive instruction development*, *7*(4), 10-14.

25. Dringus, L. P., & Cohen, M. S. (2005). An adaptable usability heuristic checklist for online courses. In *Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference* (pp. T2H-6). IEEE.

26. Freire, L. L., Arezes, P. M., & Campos, J. C. (2012). A literature review about usability evaluation methods for e-learning platforms. *Work-Journal of Prevention Assessment and Rehabilitation*, *41*, 1038.

27. Georgiakakis, P., Papasalouros, A., Retalis, S., Siassiakos, K., & Papaspyrou, N. (2005). Evaluating the usability of web-based learning management systems. *THEMES in Education*, *6*(1), 45-59.

28. Granić, A., Glavinić, V., & Stankov, S. (2004). Usability evaluation methodology for web-based educational systems. In *Proceedings of the 8th ERCIM Workshop on User Interfaces for All* (pp. 28-29).

29. Granić, A. (2008). Experience with usability evaluation of e-learning systems. *Universal Access in the Information Society*, *7*(4), 209-221.

30. Granić, A., & Ćukušić, M. (2011). Usability testing and expert inspections complemented by educational evaluation: A case study of an e-learning platform. *Journal of Educational Technology & Society*, *14*(2), 107-123.

31. Guo, Y., Wang, J., Moore, J., Liu, M., & Chen, H. L. (2009, December). A case study of usability testing on an asynchronous e-learning platform. In *Pervasive Computing (JCPC), 2009 Joint Conferences on* (pp. 693-698). IEEE.

32. Hayes, R. (1999). Exploring discount usability methods to assess the suitability of online course delivery products. *The Internet and higher education*, *2*(2), 119-134.

33. Hock, S. Y., Omar, R., & Mahmud, M. (2015). Comparing the Usability and Users Acceptance of Open Sources Learning Management System (LMS). *International Journal of Scientific and Research Publications, 5* (4).

34. Hsu, C. M., Yeh, Y. C., & Yen, J. (2009). Development of design criteria and evaluation scale for web-based learning platforms. *International Journal of Industrial Ergonomics*, *39*(1), 90-95.

35. Iding, M., Auernheimer, B., Crosby, M., & Klemm, E. (2002, January). Guidelines for designing evaluations of web-based instructional materials. In *hicss* (p. 139c). IEEE.

36. Ingram, A. L. (2002). Usability of alternative web course structures. *Computers in the Schools*, *19*(3-4), 33-47.

37. Inversini, A., Botturi, L., & Triacca, L. (2006). Evaluating LMS usability for enhanced elearning experience. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications* (Vol. 2006, No. 1, pp. 595-601).

38. ISO/IEC. 9241-14 Ergonomic requirements for office work with visual display terminals (VDT)s - Part 14 Menu dialogues, ISO/IEC 9241-14: 1998 (E), 1998.

39. Ivanović, M., Putnik, Z., Komlenov, Ž., Welzer, T., Hölbl, M., & Schweighofer, T. (2013). Usability and Privacy Aspects of Moodle: Students' and Teachers' Perspective. *Informatica*, *37*(3).

40. Jones, M. G., & Okey, J. R. (1995). Interface design for computer-based learning environments. Retrieved on October 2015, from http://www.informatikdidaktik.de/HyFISCH/Multimedia/Learning/InterfaceDesignJones.htm.

41. Kakasevski, G., Mihajlov, M., Arsenovski, S., & Chungurski, S. (2008, June). Evaluating usability in learning management system Moodle. In *Information Technology Interfaces, 2008. ITI 2008. 30th International Conference on* (pp. 613-618). IEEE.

42. Katsanos, C., Tselios, N., & Xenos, M. (2012, October). Perceived usability evaluation of learning management systems: a first step towards standardization of the System Usability Scale in Greek. In *Informatics (PCI), 2012 16th Panhellenic Conference on* (pp. 302-307). IEEE.

43. Kiget, N. K., Wanyembi, G., & Peters, A. I. (2014). Evaluating Usability of E-Learning Systems in Universities. *International Journal of Advanced Computer Science and Applications*, *5*(8), 97-102.

44. Kirner, T. G., Custodio, C. A., Kirner, C. (2008). Usability Evaluation of the Moodle System from the Teachers' Perspective. IADIS International Conference e-Learning.

45. Koulocheri, E., Soumplis, A., Kostaras, N., & Xenos, M. (2011). Usability inspection through heuristic evaluation in e-Learning environments: The LAMS case. In VII International Conference on ICT in Education, Challenges (pp. 617-630).

46. Lalande, N., & Grewal, R. (2012, July). Blackboard vs. Desire2Learn: A system administrator's perspective on usability. In *International Conference on Education and e-Learning Innovations*.

47. LMS Usability Working Group (2010). LMS Usability Evaluation Report. Tufts University.

48. Machado, M., & Tao, E. (2007, October). Blackboard vs. moodle: Comparing user experience of learning management systems. In *Frontiers In Education Conference-Global Engineering: Knowledge Without Borders, Opportunities Without Passports, 2007. FIE'07. 37th Annual* (pp. S4J-7). IEEE.

49. Marksbury, N., & Zhang, Q. (2010). A Pilot Study of CMS Usability Testing: Blackboard and Moodle. Retrieved on September 2015 from http://www.nlm.me/pubs/cmsstudy.pdf.

50. Martin, F. (2008). Blackboard as the learning management system of a computer literacy course. *Journal of Online Learning and Teaching*, *4*(2), 138-145.

51. Martin, L., Martínez, D. R., Revilla, O., Aguilar, M. J., Santos, O. C., & Boticario, J. G. (2008). Usability in e-Learning Platforms: heuristics comparison between Moodle, Sakai and dotLRN. In *Sixth International Conference on Community Based Environments. Guatemala* (pp. 12-16).

52. Mehlenbacher, B., Bennett, L., Bird, T., Ivey, M., Lucas, J., Morton, J., & Whitman, L. (2005). Usable e-learning: A conceptual model for evaluation and design. Theories, Models, and Processes in HCI, 4, 1-10.

53. Melton, J. (2004). The CMS Moodle: A heuristic evaluation. *JALTCALL2004, Mito, Japan. Retrieved on December*, *2*, 2015, from http://www.pu-kumamoto.ac.jp/~jay/pres/2004/jaltcall/moodleheuristics.pdf.

54. Melton, J. (2006). The LMS Moodle: a usability evaluation. Retrieved October, 7, 2015, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.124.7533&rep=rep1&type=pdf.

55. Miller, M. (2005) Usability in E-Learning. Learning Circuits, January 2005.

56. Minović, M., Štavljanin, V., Milovanović, M., & Starčević, D. (2008, January). Usability issues of e-learning systems: Case-study for Moodle learning management system. In *On the Move to Meaningful Internet Systems: OTM 2008 Workshops* (pp. 561-570). Springer Berlin Heidelberg.

57. Mtebe, J. S., & Kissaka, M. M. (2015, May). Heuristics for evaluating usability of Learning Management Systems in Africa. In *IST-Africa Conference, 2015* (pp. 1-13). IEEE.

58. Nielsen, J. (1994). Heuristic evaluation. *Usability inspection methods*, *17*(1), 25-62.

59. Ozkan, S., & Koseler, R. (2009). Multi-dimensional students' evaluation of e-learning systems in the higher education context: An empirical investigation. *Computers & Education*, *53*(4), 1285-1296.

60. Oztekin, A., Kong, Z. J., & Uysal, O. (2010). UseLearn: A novel checklist and usability evaluation method for eLearning systems by criticality metric analysis. *International Journal of Industrial Ergonomics*, *40*(4), 455-469.

61. Oztekin, A. (2011). A decision support system for usability evaluation of web-based information systems. *Expert Systems with Applications*, *38*(3), 2110-2118.

62. Oztekin, A., Delen, D., Turkyilmaz, A., & Zaim, S. (2013). A machine learning-based usability evaluation method for eLearning systems. *Decision Support Systems*, *56*, 63-73.

63. Padayachee, I, Kotzé, P and Van der Merwe, A. 2011. Course management systems from a usability perspective. Alternation: Interdisciplinary Journal for the Study of the Arts and Humanities in Southern Africa, Vol 18(1), pp 297-317.

64. Peimbert, R., Limon J., & Beruvides, M. G. (2012). State-of-the-Art Matrix Analysis of Total Productive Maintenance (TPM)," ASEM Annual Conference Proceedings, CD-ROM Virginia Beach, VA.

65. Penha, M., Correia, W. F. M., da Costa Campos, F. F., & Barros, M. D. L. N. (2014). Heuristic Evaluation of Usability-a Case study with the Learning Management Systems (LMS) of IFPE. *International Journal of Humanities and Social Science*, *4* (6), 295-303.

66. Piguet, A., & Peraya, D. (2000). Creating web-integrated learning environments: An analysis of WebCT authoring tools in respect to usability. *Australasian Journal of Educational Technology*, *16*(3).

67. Pipan, M., Arh, T., & Blazic, B. J. (2007, August). Evaluation and selection of the most applicable learning management system. In *Proceedings of the 7th WSEAS International Conference on Applied Informatics and Communications* (Vol. 7, pp. 350-354).

68. Rahman, K. A., Ghazali, S. A. M., & Ismail, M. N. (2010). The effectiveness of learning management system (LMS) case study at Open University Malaysia (OUM), Kota Bharu Campus. *Journal of Emerging Trends in Computing and Information Sciences*, *2*(2), 73-79.

69. Reeves, T. C., Benson, L., Elliott, D., Grant, M., Holschuh, D., Kim, B., Kim, H., Lauber, E., & Loh, S. (2002). Usability and Instructional Design Heuristics for E-Learning Evaluation. Retrieved on December 3, 205, from http://files.eric.ed.gov/fulltext/ED477084.pdf.

70. Rosato, J., Dodds, C., & Laughlin, S. (2007). Usability of course management systems by students. *Dept. Computer Information Systems/Computer Science, College of Scholastica, Duluth*. Retrieved on December 2, 2015, from http://www.micsymposium.org/mics_2007/Rosato.pdf.

71. Sandnes, F., Jian, H., Hagen, S., & Talberg, O. (2007). Student evaluation of the learning management system fronter from an HCI perspective. In *International Conference on Engineering Education–ICEE*.

72. Shahid, S., & Abbasi, M. S. (2014). Usability Testing of an E-Learning System: A Comparative study of two Evaluation Techniques. *IOSR Journal of Computer Engineering (IOSR-JCE), 16* (6), 39-43.

73. Shehu, V., Besimi, A., Abazi, L., & Shaqiri, M. (2009, June). Usability issues while building a new LMS. In *ITI* (pp. 317-322).

74. Silius, K., Tervakari, A. M., & Pohjolainen, S. (2003). A multidisciplinary tool for the evaluation of usability, pedagogical usability, accessibility and informational quality of web-based courses. In *The Eleventh International PEG Conference: Powerful ICT for Teaching and Learning* (Vol. 28).

75. Simon, K. (2016). Pareto Chart. *Retrieved on Jan 24, 2016 from http://www.isixsigma.com/tools-templates/pareto/pareto-chart-bar-chart-histogram-and-pareto-principle-8020-rule/*

76. Ssemugabi, S. & De Villiers, R. (2007). Usability and Learning: A Framework for Evaluation of Web-Based e-Learning Applications. In C. Montgomerie & J. Seale (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007 (pp. 906-913). Chesapeake, VA: AACE.

77. Ssemugabi, S., & De Villiers, R. (2007). A comparative study of two usability evaluation methods using a web-based e-learning application. In *Proceedings of the 2007 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries* (pp. 132-142). ACM.

78. Storey, M. A., Phillips, B., Maczewski, M., & Wang, M. (2002). Evaluating the usability of Web-based learning tools. *Journal of Educational Technology & Society*, *5*(3), 91-100.

79. Subramanian, P., Zainuddin, N., Alatawi, S., Javabdeh, T., Hussin A. (2014). A study of comparison between Moodle and Blackboard based on case studies for better LMS. *Journal of Information Systems Research and Innovation, (6).* (pp. 26-33).

80. Sumanth, D. J., Omachonu, V.K., & Beruvides, M. G (1990). A Review of the State-of-the-Art Research on White-Collar/Knowledge Worker Productivity. International Journal of Technology Management, Vol. 5, No. 3, pp. 337-355.

81. Tee, S. S., Wook, T. S. M. T., & Zainudin, S. (2013). User Testing for Moodle Application. *International Journal of Software Engineering and Its Applications*, *7*(5).

82. Thuseethan, S., & Kuhanesan, S. (2014). Usability Evaluation of Learning Management Systems in Sri Lankan Universities. *arXiv preprint arXiv:1412.0197*.

83. Tolk, J., Cantu, J., & Beruvides, M. G. (2015). High Reliability Organization Research: A Literature Review for Healthcare. Engineering Management Journal, vol. 27, no. 4, pp. 218-237, 2015.

84. Triacca, L., Bolchini, D., Botturi, L., & Inversini, A. (2004). Mile: Systematic usability evaluation for e-Learning web applications. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications* (Vol. 2004, No. 1, pp. 4398-4405).

85. Tselios, N. K., Avouris, N. M., Dimitracopoulou, A., & Daskalaki, S. (2001). Evaluation of distance-learning environments: Impact of usability on student performance. *International Journal of Educational Telecommunications*, *7*(4), 355-378.

86. Unal, Z., & Unal, A. (2011). Evaluating and comparing the usability of web-based course management systems. *Journal of Information Technology Education: Research*, *10*(1), 19-38.

87. Unal, Z., & Unal, A. (2014). Investigating and Comparing User Experiences of Course Management Systems: BlackBoard vs. Moodle. *Journal of Interactive Learning Research*, *25*(1), 101-123.

88. Van Greunen, D., & Wesson, J. (2002). Formal usability testing of interactive educational software: A case study. In *Usability* (pp. 161-176). Springer US.

89. Walker, S., Prytherch, D., & Turner, J. (2013, September). The pivotal role of staff user experiences in Moodle and the potential impact on student learning. In *e-Learning and e-Technologies in Education (ICEEE), 2013 Second International Conference on* (pp. 192-197). IEEE.

90. Watson, W. R., & Watson, S. L. (2007). What are learning management systems, what are they not, and what should they become?. *TechTrends*, *51*(2), 29.

91. Zaharias, P., Vasslopoulou, K., & Poulymenakou, A. (2002). Designing on-line learning courses: Implications for usability. *Scientific Journal on Applied Information Technology*, *1*(1).

92. Zaharias, P. (2006, April). A usability evaluation method for e-learning: focus on motivation to learn. In *CHI'06 Extended Abstracts on Human Factors in Computing Systems* (pp. 1571-1576). ACM.

93. Zaharias, P., & Poylymenakou, A. (2009). Developing a usability evaluation method for e-learning applications: Beyond functional usability. *Intl. Journal of Human–Computer Interaction*, *25*(1), 75-98.