A MODEL FOR USABILITY EVALUATION OF LEARNING MANAGEMENT SYSTEMS

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ABSTRACT

Learning management systems (LMSs) are increasingly popular in education. The usability of these systems must be examined to ensure they meet the needs of both students and faculty. To address the limitations of existing models for evaluating the usability of LMS, this research proposes a new model that combines objective measures collected from eye-tracking with subjective measures collected from retrospective think-aloud protocols and questionnaires. This model evaluates the effectiveness, efficiency, satisfaction, and learnability of LMSs. The proposed model was applied to study the usability of the LMS used at King Saud University (Blackboard) and was compared with other existing usability evaluation models. The findings indicate that the proposed model fulfilled its intended purpose and provided more comprehensive results than existing models.

KEYWORDS

Usability, usability evaluation methods, learning management system, LMS, Blackboard.

1. INTRODUCTION

Usability is an essential element in Human-Computer Interaction (HCI). According to the Institute of Electrical and Electronics Engineers (IEEE), usability defines how quickly a user is able to understand how to operate, supply inputs to, and understand results from a system or device [1]. Basically, without usability, there is no guarantee for the successfulness of a system although it may be functionally precise and accurate [2]. Due to the COVID-19 crisis, E-learning has become essential. However, this would not be that fruitful without usability and usefulness [2]. E-learning is an innovative technology that aims at promoting the quality of the educational processes [3]. Learning Management System (LMS) is the most common name found in the research of E-learning [4]. Numerous techniques are utilized to evaluate the usability of LMSs. Selecting the appropriate technique for evaluation is governed by the functionality and complexity of the LMS and occasionally by the system objectives [5]. This study reviews the current state of the techniques used in evaluating the usability of LMSs and presents a model for usability evaluation of LMSs combining objective and subjective measures.

2. RELATED WORK

The rapid advancement of technology in education has become so widespread that institutions have been compelled to adapt and modify their teaching processes to incorporate these technological advancements [6]. Learning management systems are a prime example of the technologies that are widely utilized in higher education. The diversity of the LMSs available on the market is extensive however they all share the common purpose of managing and organizing the learning process and help in delivering course materials to a wide remote educational forum

[7]. Some available LMS are; Blackboard, Moodle, WebCT, Lotus Notes, ELeaP, Elogic, Geo-learning Inc ,Point Cast, Joomla, E-front , Sakai and A-Tutor [7].

2.1. Usability

The most important factor influencing the quality of an E-learning platform is usability [8]. This factor might influence the learning experience of the users [9]. Therefore, it is essential that LMSs have an adequate usability level. There are various usability definitions provided by many authors [10]. According to ISO 9241-11 [11], usability defines how easily can users complete their goals with efficiency, effectiveness, and satisfaction in a specific context. In addition, IEEE Std.610.12-1990 [12] identifies usability as the ease with which a user can learn to use, organize inputs, and understand outputs of a system. Moreover, Brinck [13] defines usability as the extent to which a user can accomplish the basic essential tasks. As stated, usability has been identified by various standards and models in different ways. To illuminate this concept, Table 1 shows the usability attributes of various well-known standards and models.

Table 1: Main attributes of usability from different standards/models

Main Attributes	**ISO9214-11** [11]	**ISO25000Series** [14]	**Nielsen** [15]	**McCall** [16]	**Quesenbery** [17]	**Brinck** [13]	**Schneiderman** [18]	**Furps** [19]	**Shackel** [20]	**Donyaee** [21]	**Abran** [22]
Accessibility		√								√	
Aesthetic								√			
Consistency								√			
Documentation								√			
Effectiveness	√	√	√	√	√				√	√	√
Efficiency	√	√			√	√	√		√	√	√
Engagement					√						
Error tolerance			√		√	√	√				
Human Factors								√			
Learnability		√	√		√	√	√		√	√	√
Memorability			√			√	√				
Operability		√		√							
Productivity										√	
Safety										√	
Satisfaction	√	√	√			√	√		√	√	√
Security											√
Training				√							
Universality										√	
Usefulness										√	

As demonstrated in Table 1, the most common attributes that are considered necessary to evaluate the usability of any system regardless of its context are effectiveness, efficiency, satisfaction, and learnability.

- Effectiveness: Refers to the capability of a specific user to completely and accurately achieve specified goals in specific environments [23]. Effectiveness metrics include task completion rate with and without help, and error rate [24].
- Efficiency: Refers to the resources used to accomplish a goal accurately [23]. Efficiency metrics include time to find the options/controls, number of mouse clicks required, and total time spent on task [24].
- Satisfaction: Refers to the user opinions and feelings when using the system [23]. It is a subjective response from the user about their feelings during the interaction with the system [24].
- Learnability: Refers to how quickly novice users can learn to operate with the system and perform tasks [23]. It is a necessary usability attribute, as most systems or products need to be learned as easily as possible. According to Kakasevski et al. [25], it is a crucial characteristic when evaluating learning management systems.

2.2. Usability of Learning Management Systems

Godfred et al. [26] state that a significant obstacle in utilizing LMS for online learning is the absence of necessary IT proficiency among both educators and learners. This highlights the importance of enhancing the system's usability to cater to users with varying levels of technical expertise. Numerous techniques are used for evaluating the usability of LMSs. These techniques vary from simple methods, such as survey, to more complex methods, such as using eye-tracking. Selecting the appropriate technique for the evaluation is governed by the functionality and complexity of the LMS and occasionally on the system objectives [9]. Among these techniques, questionnaire is the commonly used method due to its ability to reach a wide sample size in a short period. Several studies [9], [10], [27] used questionnaires to evaluate the usability of LMSs. Although questionnaires can collect vast amounts of data in a short time, it cannot provide reliable results when applied alone [28]. Questionnaires or surveys are also not very accurate [29]. This is usually due to certain factors, such as the return of incomplete questionnaires, completed by someone other than the respondent or falsified responses of those who completed the forms ‘just for the fun’. Other studies [30]–[32] evaluated the usability of LMSs using user testing. The result of Melton et al. [32] shows that although none of the participants have faced any critical issues that blocked them from registering to Moodle, half of them were not able to submit their assignments. The participants pointed out that using English interface made task competition more complex compared to using Japanese interface. This result in line with [31] which emphasized the importance of using students’ language for the interface of LMS. While user testing can identify serious problems and recurring problems [33]. It is time consuming, requires high cost and prone to missing consistency problems [33], [34]. Eye-tracking is another technique that can be used for usability evaluation. It provides researchers with users' visual data such as gaze direction and visual attention, which can help in representing the learning materials and reveal many usability issues [35]. Several studies [3], [35], [36] have employed eye-tracking in usability evaluation. Ramakrisnan et al. [3] used eye-tracking to evaluate the usability of LMS. The analysis from the students’ eye movement patterns in terms of both gaze plot and heat map revealed some design issues. As a result of this analysis, solutions for the identified design issues were proposed. Although, eye tracking enables directly asking the brain, not the person which offers unbiased measurements of decision[37]–[39]. The analysis of the gaze plots requires intensive effort [24] and prone to subjectivity in the analysis of the data, which is influenced by the expertise and experience of the researchers [36]. Another important and widely used technique to evaluate the usability is think-aloud protocol [15]. Using this method, subjects describe what they think is happening and explain any difficulties that they experienced while using the system. Several studies used the think-aloud method with a combination of other UEMs [40]. Think-aloud protocol was used by Thacker et al. [41] to evaluate the usability of two LMSs: Clemson University’s Blackboard and Canvas. The researchers conducted a comparative

usability study. Five staff members from the university participated in the usability experiment. They perform five common tasks using both Blackboard and Canvas platforms, using think-aloud protocol accompanied by short pre- and post-study assessments. The data resulting from the study were analyzed using Strauss and Glaser's Grounded Theory method to conceptualize trends and ultimately identify usability issues in the software. The conclusion explicitly recommended the replacement of the present Blackboard solution by the Canvas LMS. Although, think aloud protocol can gain insight into the user experience, preferences and performance information [42], [43]. Concurrent think aloud may distract the user and affect the performance of the task [42], [44].

3. HYBRID MODEL

Proposing a usability model involves selecting the usability attributes to be measured and the most suitable usability method. The proposed model assesses the most examined usability attributes appeared in various standards and models, as illustrated in Table1. Figure 1 shows the usability attributes of the hybrid model.

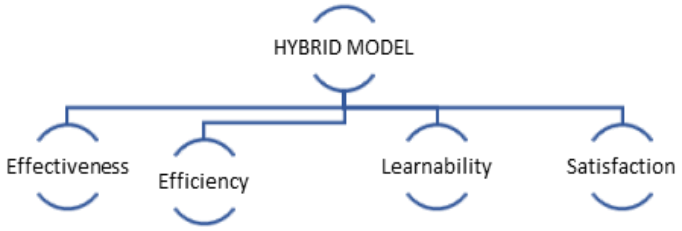

Figure 1: Usability attributes of the hybrid model

Effectiveness, efficiency, and learnability are attributes that have objective characteristic, whereas satisfaction has subjective characteristic. Thus, there is a need to integrate both objective and subjective measures to measure the proposed usability attributes. Several research highlighted the inadequacy of traditional usability evaluation methods to evaluate the usability of LMS. According to Pipan et al. [45], traditional usability testing techniques are not adequate for a comprehensive usability study of e-learning systems . Additionally, according to Fenu et al. [46] traditional usability testing techniques are not adequate because the aim of E-learning systems is not only to interact but also to maintain knowledge acquisition and dissemination. Moreover, Zaharias et al. [47] concurred that traditional usability assessment techniques do not take into account the constructivist view that learners must be engaged with their own learning and have an intrinsic motivation to learn beyond simply completing tasks. Adebesin et al. [48] pointed out that the unique nature of e-learning systems necessitates different methods of usability evaluation. Liu et al. [49] added that a combination of objective and subjective measures is necessary for a comprehensive assessment of E-learning systems. In correspondence, Freire et al. [50] agreed that combining multiple methods has been shown to be the most effective way to evaluate the usability of E-learning systems. Several studies, including [34], [49], [50], have concluded that it is essential to give users more voice when assessing E-learning systems, even with the adaptation of new multidisciplinary methods. Integrating different evaluation methods with different user profiles, not for comparison but as comprehensive evidence, will add a valuable information to the obtained results.

Our hybrid model combines several usability evaluation methods while giving more voice to the subjects. The choice of methods was based on a systematic literature review of the usability evaluation methods used for evaluating LMS. The review showed that Eye-tracking is the best method, only losing out on price. As such, the proposed model focuses mainly on using Eye-

tracking. This offers an objective view into a user's cognitive processes during computing tasks and can reveal usability problems that users may not be aware of. Traditional UEMs may not be able to expose biases in subjects' responses caused by artificial testing environments, but eye-tracking data can account for these biases and provide more valid usability findings. Another advantage of using eye-tracking in usability testing is its practicality. It offers an insight into the origins of a problem in contrast to traditional usability methods, which reveal data only on a descriptive level. It allows a comprehensive analysis of the stages where the issues arise. However, the solely use of eye-tracking may result in subjectivity in the interpretation of the gaze data, influenced by the expertise and experience of the researchers. Thus, the proposed model combines eye-tracking with retrospective think-aloud (RTA) for better identification of problems. Concurrent think aloud protocol cannot be used with eye-tracking because it is unusual to many people. Participants might find it difficult to continuously express their thoughts while using the system [51]. This protocol may double stress the user, leading to prolonged answer, huge fixation time, and long saccade path. Thus, the proposed hybrid model recommended retrospective think-aloud protocol to be integrated with eye-tracking. The hybrid model assessed the most examined usability attributes appeared in various standards and models including effectiveness, efficiency, learnability, and satisfaction. The former three components, which have objective characteristics, were measured combining eye-tracking and RTA. However, satisfaction is a component that has subjective characteristics. To measure this component, we integrated the hybrid model with the SUS, which has been proved by many studies to be valid and reliable even for small sample size [52]. The integration of such subjective measures, SUS, and RTA, gives more voice to the users as well as adds more value to the sum of the obtained results.

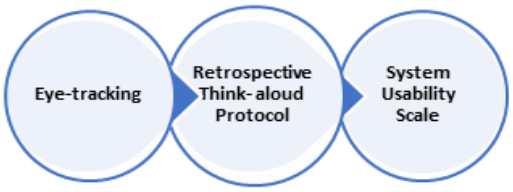

Figure 2: UEMs integrated in the Hybrid model.

3.1. Effectiveness

Refers to the ability of a student to achieve completely and accurately specific goal within the LMS. Based on this definition, it is a component that has objective characteristic. Therefore, it is measured using a usability measurement extracted from eye-tracking and retrospective think aloud protocol.

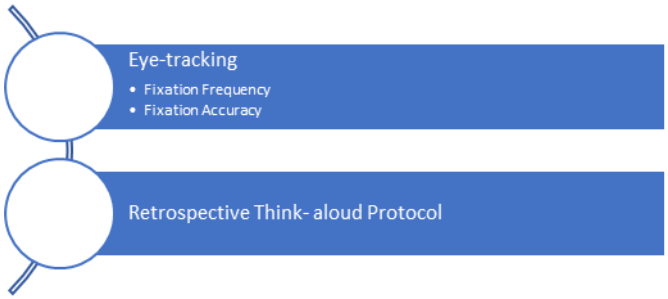

Figure 3: Metrics used to measure the effectiveness.

3.1.1. Eye-tracking metrics:

- Fixation frequency: it represents the total number of fixations presented while performing a task. To recognize the distinctions in fixations across various areas of interest (AOIs), the following metrics of fixation frequency need to be analysed:
  - All fixations frequency
  - Fixations on AOI frequency
  - Fixations away from AOIs frequency
- Fixation accuracy: it represents the percentage of all fixations occurring on a specific AOIs. This metric normalizes fixations on AOIs according to the total number of fixations.

3.2. Efficiency

Refers to the resources used to accomplish a goal accurately [23]. It is a component that has objective characteristic. Therefore, it is measured using a usability measurement extracted from eye-tracking and retrospective think aloud protocol.

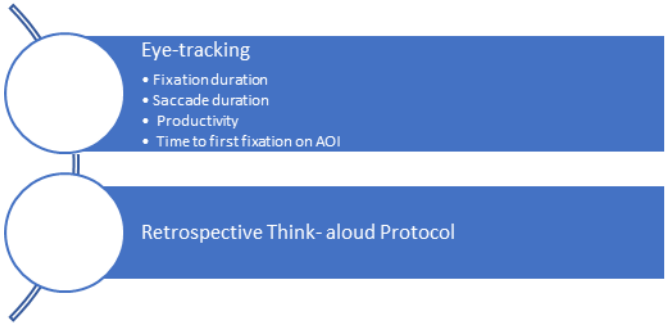

Figure 4: Metrics used to measure the efficiency.

3.2.1. Eye-tracking metrics:

- Fixation duration: it represents the total amount of fixations time spend while performing a task. To recognize the distinctions in fixations duration across various areas of interest (AOIs), the following metrics of fixation duration need to be analysed:
  - All fixations duration
  - Fixations on AOI duration
  - Fixations away from AOIs duration
- Saccade duration: it represents the total amount of time spend in moving the eyes from one AOI to other AOI (saccades) while performing a task.
- Productivity: it represents the percentage of fixation time spent on specific AOI over fixation time on all AOIs. This metric normalizes fixation duration on AOIs according to the fixation duration of the experiment trial.
- Time to first fixation on AOI: it represents the amount of time it took the participant to first fixation on a targeted AOI.

3.3. Learnability

It reflects how quickly novice users can learn to operate with the LMS. Based on this definition, it is a component that have objective characteristic. Therefore, it is measured using a usability measurement extracted from eye-tracking. Eye-tracking is a useful tool to assess learnability [53], [54].

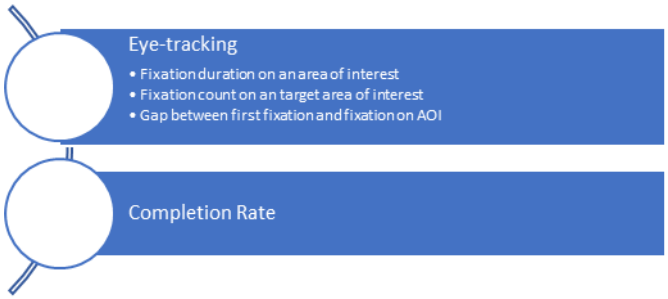

Figure 5: Metrics used to measure the learnability

3.3.1. Eye-tracking metrics

- Fixation duration on an AOI: it represents the amount of time spends to acquire information from a specific area. smaller fixation duration determines that it is easy to understand the interface.
- Fixation count on a target area of interest: it represents the number of fixations on specific AOI. high fixations count sometime indicates uncertainty and confusion as the eye move in and out of the AOI frequently to be sure.
- Gap between first fixation and fixation on AOI: it represents the amount of time from the first fixation on the interface till the first fixation on the target AOI. A smaller value indicates that the target AOI can be reached easily, and the interface is predictable**.**

3.3.2. Completion rate

It calculates the percentage of participants who finish the task successfully over the total number of participants. High rate indicates that the system is easy to learn.

3.4. Satisfaction

It refers to the students' opinions and feelings when using the LMS. Based on this definition, it is a component that have subjective characteristic. Therefore, it is measured using a post-test questionnaire; system usability scale (SUS). This post-test questionnaire consists of 10 questions concerning the system overall satisfaction.

4. CASE STUDY

This section discusses the case study that is applied in the current research. It begins by discussing the participants, apparatus, stimuli, tasks, and procedure used in detail. It continues by presenting the pilot test. Lastly, it presents the results and discussion of the experiment that is conducted to examine the applicability of the hybrid model to evaluate the usability of LMS, and its ability to measure effectiveness, efficiency, learnability, and satisfaction.

4.1. Participants

The sample involved 15 participants as representative users in the usability evaluations. This representative sample consists of novice, experienced and highly experienced users. The formation of the participant into these groups is essential to measure the learnability of the LMS.

Table 2: Participants' background

	Novice	**experienced**	**highly experienced**
Language	Read and speak Arabic and English		
Sex	Female		
Age	18-25		
Blackboard LMS Experience	Have not used Blackboard LMS before at all	Have used Blackboard LMS for 1 year at least and no more than one and half year	Have used Blackboard LMS for 3 years at least
Blackboard LMS usage Frequencies	Zero	5-7 times/week	8-13 times/week
Internet Use	Must have 5 hours/day minimum internet usage		

4.2. Apparatus

The usability test was conducted in the usability lab at King Saud University. Specialized testing hardware and software were used to gather the usability data:

4.2.1. Eye-tracking device

The eye-tracking device recorded the participants' eye movements and captured the direction and focal points of their gazes. We used a Tobii X120 eye-tracking system, which uses infrared corneal reflection to measure gaze points. The Tobii X120 report defined its accuracy to be within 0.5°. Head movement is permitted within a 44 x 22 cm at 70 cm volume centered. In addition, the operating distance is up to 80 cm from the eye-tracker.

4.2.2. Screen

The eye-tracking device was connected to a 22 inch Dell screen with a 1600x1200 resolution.

4.2.3. Eye-tracker software

Tobii Studio 3.2.1 software was used to record and analyze the eye gaze data. It enables playback of the sessions' records with or without eye movements. It contains a feature that allows for retrospective think-aloud record. This feature This allows the facilitator to record the participant's comments and reactions through video or audio while reviewing the session's recording. Moreover, it allows for speed adjustment of the session's record. Facilitator can start, pause (i.e., participant needs extra time to respond), rewind or fast-forward the session's record.

4.3. Stimulus

The Blackboard learning management system used at King Saud University was used as stimuli for this experimental study.

4.4. Tasks

Sixteen main representative tasks were performed by the participants in the same order to test the usability of various areas of KSU's Blackboard LMS. These tasks were carefully developed based on experience of using the system for two years as a student as well as observing the students usage of the system during labs time for one semester as an instructor. The participants were instructed to carry out the designated tasks:

1. Change the interface language to Arabic.
2. Login to the system.
3. Find Course.
4. View announcement.
5. View slide.
6. View Assignment.
7. Submit Assignment.
8. View Assignment grade.
9. View the instructor feedback on Assignment.
10. Create a group.
11. Send email to a team a team member.
12. Send email to your instructor.
13. View the calendar.
14. Add event to the calendar.
15. Delete an event from the calendar.
16. Use the discussion board.

4.5. Procedure

The experiment's sessions began with a brief explanation of the purpose of the study, the Blackboard LMS and its main features, and the equipment used in the testing. After that, participants were asked to sign a consent form to get their permission on capturing their eye movements and recording their audio during the session. Participants also were provided with a demographics questionnaire that included items on sex, age, language, education, Blackboard LMS Experience, Blackboard LMS usage frequencies and Internet usage. Then, a calibration test was conducted with a 5- point calibration to correctly trace each participant's eye movements before the start of the evaluation session. If the calibration test was successful, the participant was instructed to perform a series of tasks. However, if the calibration test failed, the participant was excluded from the study. After the completion of the tasks, participants were asked to use retrospective think aloud to describe their actions while viewing their gaze plots records. Lastly, the participants were asked to complete the SUS questionnaire to rate their satisfaction of the Blackboard LMS. It is worth to mention that each session leased approximately 1 hour.

5. VALIDATION OF THE HYBRID MODEL

We compared the outcomes of applying our proposed hybrid model, as well as three other existing models (Eye-tracking, RTA and Nielsen's heuristics) to KSU's Blackboard LMS to validate the model and reveal any usability issues. The usability issues reported in the second column of Table 2 are revealed by the observation of the gaze plots data only, without any specification from the data gathered during RTA. Similarly, in the case of applying RTA, the issued are reported by the participants during the RTA session without any interruption from the facilitator. During the sessions with the hybrid model, the issues are revealed based on the discussions with the participants elaborating on their experiences and interpretations about abnormal observations such as long fixation duration, long saccade path or backtrack saccade

while viewing their gaze recording. In addition, four HCI experts evaluated the LMS using Nielsen's heuristics evaluation. One of them had a PhD in Human Computer Interaction, one had a PhD in Computer Engineering and two had MSc in human computer Interaction.

Table 3: Number of usability issues revealed by the different models.

Heuristics / Model	**Hybrid model**	**Eye-tracking**	**RTA**	**Nielsen's Heuristics**
Visibility	7	1	2	0
Match between system and real world	3	1	2	2
User control	3	2	1	0
Consistency	4	2	1	1
Error prevention	2	0	2	1
Recognition rather than recall	2	0	2	2
Flexibility and efficiency	0	0	0	0
Aesthetic and minimalist design	7	3	4	3
Error recovery	2	2	0	1
Help and documentation	1	0	1	1
Total usability issues	31	11	15	11

Table 3 shows the number of different usability issues reveled by four usability evaluation models: the hybrid model, eye- tracking, RTA and Nielson Heuristic. The issues were classified in to 10 categories based on the violated Nielsen's heuristics. The hybrid model was able to reveal 31 usability issues while the other existing usability evaluation models including eye- tracking, RTA and Nielson Heuristics were able to reveal only 11, 15 and 11 usability issues, respectively. This comparison proves the ability of the hybrid model to reveal usability issues that were uncovered using existing evaluation models.

6. CONCLUSION

The hybrid model was able to discover some usability issues that were not revealed by other existing UEMs including heuristic evaluation, eye-tracking and retrospective think aloud. Nielson's heuristic evaluation offered fast results compared to the hybrid model. However, it was not able to reveal most of the usability issues in the LMS. Experts missed some real usability problems, as the assessment was subjective to their experience. The results show that they focused on some part of the system while neglecting the other, which results in discovering less usability issues. Furthermore, Participants following retrospective think aloud was conservative in expressing their personal thoughts, which revealed less usability issues. In addition, analysis based on eye-tracking data was found to be influenced by the expertise and experience of the researchers. There was considerable subjectivity in the interpretation of the gaze plot results. What may be considered as a long fixation for one researcher may be considered as a regular fixation for other researchers. Besides, the utilization of eye-tracking solely does not allude to the participants' subjective experience, which concealed many usability issues. On the other hand, the hybrid model was able to provide the evidence that encourage participants to speak. With the evidence based on the eye-tracking data, including large fixation count, long fixation duration, long saccade path, and backtrack saccade path, participants pointed out more usability issues concerning the system visibility, match between system and the real world, consistency, and user control. In conclusion, the finding shows that the hybrid model was able to fulfil its intended purpose. Applying the hybrid model allows researchers to gather detailed quotes, which leads to

better identification of the usability issues as well as aid in providing solutions to the discovered issues.

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