Research online Publishing
www.ronpub.com

Open Access

Open Journal of Information Systems (OJIS)
Volume 1, Issue 1, 2020
http://www.ronpub.com/ojis
ISSN 2198-9281

Usability Testing and Evaluation of Multimedia E-Learning Management System in Higher Education: Criteria for Evaluation

Taurayi Rupere, Maria Jakovljevic

School of Computing, University of South Africa, Unisa Science Campus, Florida, Roodepoort, Johannesburg, South Africa, taurai.rupere@gmail.com, jakovm@unisa.ac.za

Abstract

This paper discusses the criteria for usability testing and evaluation of Multimedia e-Learning Management Systems (MEMS). This was achieved through an in-depth analysis and synthesis of literature and presentation of results of a practical application using the University of Zimbabwe MEMS, Towards Student-Centred Integration of Multimedia ELearning, TSIME. Firstly, a critical review, analysis and synthesis of usability testing and evaluation of MEMS was done. That was followed by an in-depth synthesis of the learning theories as the structural basis of MEMS. Major criteria were drawn from MEMS usability, design aspects, institutional dimensions, and learning theories. The derived criteria were merged with the generic usability heuristics producing sixteen TSIME Usability Heuristics, TSIMEUH. Heuristic Evaluation (HE) method was used to test TSIME. The evaluation was carried out for two weeks using three expert evaluators. Twenty-eight usability problems were identified from the study, ten of which were classified as requiring high priority intervention while the rest needed moderate to minimal priority intervention and were solved. The major criteria that emanated from the study were under motivation, ethics and navigation attributes. The key findings indicated that criteria drawn can empower learning and solidify a good learning environment through the use of MEMS. The criteria also embrace a consolidated learning pattern that can be used in global pandemics such as the COVID-19 era by both instructors and learners. The research concluded that learning is embedded in the historical, social and material context and should be improved through interaction and feedback that incorporate the learning theories.

Type of Paper and Keywords

Regular research paper: *Human-Computer Interaction, Constructivism, Critical Learning Theory, Activity Theory, Situated Learning Theory, Multimedia E-learning Management Systems, Usability Testing and Evaluation, Learning Theories, Multimedia Design*

1 Introduction

Multimedia E-Learning Management Systems (MEMS) can be defined as systems that facilitate learning through electronic devices and technologies such as the Internet, audio and video, satellite devices, interactive televisions, and CD ROMS [43]. MEMS have also been characterized as interactive systems that work as operating systems that interface users and their learning devices [34]. Thus, MEMSs are learning management systems that enhance interaction between users through multimedia such as voice, text, audio, video, and pictures. MEMs make use of ubiquitous technologies such as mobile devices to deliver content [37]. The introduction of MEMS in e-Learning environments brought a lot of hype in student learning systems due to their attention-seeking, quick access to information through discovery, and personalized interfaces that attract learners' interest and attention [43]. Modern learning has become student-centered. Consequently, students now have control of their learning and are reached easily across different geographical locations. MEMS bring the missing confidence among students due to their user-friendly interfaces.

Multimedia E-Learning has been identified as an enabler in teaching and learning [37]. However, there is a higher dropout rate in technology-enabled learning with students reverting to the traditional learning methods [18]. One of the main reasons cited for the higher drop out is the poor user-friendliness of the systems and usability [57]. Users surveyed in [50] complained that the MEMSs were not giving them platform independent ability to learn and acquire new skills. MEMS's success depends on user perceptions and acceptance. This suggests the need for thorough usability testing and evaluation of MEMS.

Usability testing and evaluation is about gathering information on the current usability and potential usability of a system in order to improve it [39]. It describes the ease with which the technology interface or system design is usable [48][43]. It is a process of testing how the system or technology can be used or accepted by users. It can be done at different stages of development and by different people [12] [21] [23]. Aspects of the user interface such as navigation, content availability, interaction, and feedback and quality design components are critical issues to consider when evaluating MEMS usability.

The main aim of usability evaluation is to improve the system so that it is well accepted by users. This is done by identifying the potential problems before the commissioning of the system [19]. According to [15], a usability problem is any aspect of a design that if resolved could result in an improvement in usability. Usability problems are prioritised according to their impact [39]. Unresolved usability problems in MEMS can negatively impact the learning outcome at the later stage of the use of the system. A poorly designed user interface causes users to struggle to use the system [15]. This may lead to users developing a negative perception of the system and a reduction in learning motivation.

1.1 Tools for Evaluating MEMS

Different types of tools have been used for usability testing and evaluation of MEMS. Tools used by students and teachers on different learning management systems are discussed in [43] and [54]. They investigated whether usability problems hamper the use of navigation links, uploading and downloading tools, for example, blogs, charts, assignment feedback, forums and messaging found on the platforms from the user perspective. Usability of course management systems from a system perspective are given in [32][37][38][44]. Researchers [50][51][54] looked at usability from the system and user perspectives but focusing much on the system excluding the administrative aspects. However, to our knowledge, research covering the three aspects, no published research covers the user, the system and the administrative aspects to come up with a practical usability testing and evaluation framework for MEMS.

Guidelines by different authors [4][25][28][52][35][45] highlighted different aspects of usability and its tools for evaluating MEMS. However, some guidelines have been generalized and their application still needs more research. Of these guidelines, some looked into the effectiveness of learning tools while others researched on web applications and human factors in e-Learning [54]. Comprehensive practical frameworks for usability testing that include technological, institutional, management and user issues are still not in place. Hence, there is a need to come up with some criteria for usability testing and evaluation of MEMS in higher education. These criteria should be drawn from a broad spectrum that looks at the learning theories, epistemological frameworks to MEMS and the usability and evaluation aspects.

1.2 Research Aim, Purpose and Research Questions

The study is motivated by the lack of uptake of MEMS by users. There seems to be a lack of usability testing and evaluation of MEMS where user learning needs are not embraced in the design and implementation of MEMS. There should be criteria for usability testing and evaluation of MEMS drawn from the design aspects, institutional dimensions and the learning theories besides the generic ones used in conventional software and web applications. Finally, the research needs to identify how these criteria empower learning to users through a Heuristic Evaluation (HE) of an integrated MEMS with a Social Network Service (SNN). The main purpose of this study is to come up with criteria for usability testing and evaluation of MEMS in higher education from usability, design aspects, institutional dimensions and learning theories. The criteria are going to be the basis for usability testing and evaluation of MEMS and together with other generic evaluating tools, the study can inform how MEMS can empower learners in eLearning environments especially in global pandemic such as COVID19 where the majority of learners are learning from home. The following were the research questions of the study:

- RQ1: What are the institutional dimensions and design aspects of MEMS?
- RQ2: What are the essential learning theories that can support usability testing and evaluation of the MEMS framework in higher education?
- RQ3: What effect do the derived criteria including the generic evaluation tools have on usability testing and evaluation (HE)?
- RQ4: How do the criteria for usability testing and evaluation empower learning in e-Learning environments?

The research contributes by identifying the missing gap in the usability testing and evaluation of MEMS in higher education with an emphasis on the learning theories and institutional dimensions.

2 Usability of MEMS

In this section, usability is defined in line with this study. Also, usability categories, attributes and classification taxonomy are reviewed from different literature. Criteria for usability testing and evaluation are then derived from the usability of MEMS.

2.1 Usability Definition in the Context of This Study

There are various definitions of usability that are accepted and applied in practice [3]. The term usability may be traced to user-friendly. User friendly is an "expression used to describe computer systems which are designed to be simple to use by untrained users, using self-explanatory or self-evident interaction between user and computer" [33]. The term user-friendly was criticised in [39]. Usability has also been defined as coupling of user-friendliness with some diverse dimensions [3][42].

Abran et al. [1], defines usability as "a set of multiple concepts taken together such as user satisfaction, ease of learning, performance and execution time". This definition augers with [21], which posits that "it is the extent to which a specific product can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context". The definition centers on the effectiveness, efficiency and satisfaction of users on a product. Effectiveness is the accuracy and completeness with which users achieve specific goals. Efficiency is the resources expended concerning the accuracy and completeness with which users achieve specific goals. Lastly, satisfaction is freedom from discomfort and positive attitudes towards the use of a product. The explanation also reveals that the attributes are not absolutes but need to be assessed in the context of use.

Nielsen in [42][25][40] defined usability in the context of e-Learning as learnability, efficiency, memorability, with few errors and user satisfaction. The explanation of Nielsen [42] is in line with ISO/IEC 9126-1 and [40] which classifies usability as one of the components representing internal and external software quality. They defined usability as the capacity of the software program to be understood, learned, and used while being attractive to the user when used under specified conditions. There are five attributes of usability which are understandability, learnability, operability, attractiveness and usability compliance [3][40][46].

Understandability is the capability of a software product to enable the user to comprehend the suitability of the product for use in particular tasks under certain conditions. Learnability is the capability of the software product to enable the user to learn its application [22]. Operability is the capability of the software product to enable the user to operate and control it. Attractiveness is the appeal of the software product to the users. Usability compliance is the capability of the software product to adhere to certain standards, conventions, style guides, or regulations relating to usability.

Lastly, usability has also been explained in [36] and [47] as the capacity in human functional terms, to be used easily and effectively by a specific range of users, given specific training and user support, to fulfill a specific range of tasks, within a specified range of environmental scenarios. In this explanation, there is an aspect of training and user support as well as the environment that is not in the two previous explanations. This explanation defines usability as "the ease with which a user can learn to operate, prepare inputs for and interprets outputs of a system or components" have also common link through the ability of the user.

Further extensions on the attributes of usability are in [47][52]. Researchers noted that there are different usability perspectives and viewpoints of the users, administrators and system developers on any system [3] [8]. A key conclusion is therefore that usability is context-specific.

While usability has been studied in Web applications [18][51] and e-Learning software [24][39][44] and user-specific systems [13][14], to the best of our knowledge, there is little published research on usability in the MEMS context [11]. It has been pointed out that MEMSs have been built without input from each viewpoint group [3][8]. In this paper, we, therefore, present our study on usability in the MEMS context.

2.2 Usability Categories

Abran et al. [1], classified usability into four main categories: the organisational capability, development process, product and product effect. The organisational capability looks at the capability of the software to be understood, learned, its attractiveness and use by the user. The development process looks at the processes involved in coming up with the product. The product, thus, has attributes for interface and interaction. Lastly, the product effect looks at how users are satisfied with the product, its use and its effectiveness. MEMSs are both processes and product-oriented where the process looks at the capability and quality aspects while product looks at the use and product interface as well as interaction [2].

2.3 Usability Attributes and Classification Taxonomies

Some standards attributes of usability are discussed in [28][42] with some extensions in [40]. Seffah et al. [46] pointed out that different attributes are used for users, administrators and system developers. An integrated model for the three viewpoints while desirable does not exist. An extension of the Preece [45] and Nielson [42] has been done by [40] to come up with a set of ten attributes which are efficiency, effectiveness, productivity, satisfaction, safety, learnability, trustfulness, accessibility, universality and usefulness.

Furthermore, Alonso-Ríos et al. [3] came up with a layered classification taxonomy that critically analysed some of these attributes. That classification taxonomy removes ambiguity and overlap inherent in attributes. The first level of the taxonomy had the following six main attributes: knowability, efficiency, robustness, safety, operability and subjective satisfaction. Each attribute has sub-attributes: clarity, consistent, memorability and helpfulness came from the knowability attribute while completeness, precision, universality and flexibility described the operability attribute. Under safety attribute, they came up with user safety, environmental safety and third part safety. Interest and aesthetics were drawn from the subjective satisfaction attribute while robustness to an internal error, to improper use, to third part abuse and environment problems came from the robustness attribute. The last attribute, efficiency, came with the efficiency of human effort, task execution time, tied up resources and economic costs.

However, the classification taxonomy came up with little details and the issue of overlap was not exhaustively analysed. They concluded that usability is a complex concept because there is lack of consensus by experts on different meanings. Different systems have different aspects and attributes that are not transferable from one system to another. Of further concern, besides the aspects and attributes, are the methods that have been used to test usability, the models and the perspectives [50]. Methods, models and perspectives for testing usability vary from one system to another.

2.4 Criteria for MEMS Usability Testing and Evaluation

Table 1 details the criteria for evaluating the usability of MEMS.

The usability definition and meaning criteria (Criterion U1) explains on the MEMS being specific e-learning software targeting learners and instructors [21][22]. In terms of functionality, MEMS should be learnable to users where they should be efficient, memorable and offer user satisfaction [36][40][47]. Criterion UC1 was derived from the MEMS category [1][2]. The criterion looks at how organisations are capable to develop and implement a new or improved MEMS using the product effect and efficiency. Besides, it also looks at how MEMS are attractive through design implementation as well as how they are understood by users. Aspects of user-friendliness constitute this criterion.

Lastly, is the Criterion UA1 which as derived from the usability attributes and classification taxonomy [3][28][40]. This criterion emphasises the six key attributes for MEMS evaluation which are knowability, efficiency, robustness, safety, operability and subjective satisfaction [3]. The above criteria formed the usability evaluation thrust.

3 Learning Theories as a Basis for Testing and Evaluation of MEMS

Learning theories, relating to e-Learning, deals with how people learn [36][55]. It helps in understanding the complex process of learning. Any learning theory should have clear assumptions and brief of the object with key terms clearly defined. There should be a developmental process, where principles are derived from assumptions; and it should entail an explanation of underlying psychological dynamics of all events relating to learning [4][26][55].

The empirically-based accounts of the variables that influence the process and outcome of learning are also provided by the learning theories [36][4]. Wang [55],

Table 1: Criteria for usability and evaluation of MEMS

Criteria	Criteria Number	Explanation
Usability definition and meaning	Criterion U1	MEMS are specifice-Learning products used by specific users (learners and instructors) wherethey should be learnable with efficiency, memorability and satisfaction to users.
MEMS usability category	Criterion UC1	The organisational capability, development process,product and product effect are essential for evaluating the usability of MEMS. The software should beattractive, be understood, learned, and user-friendly.
Uability attributes and classification taxnomies	Criterion UA1	Knowability,efficiency, robustness, safety, operability and subjective satisfaction are keyusability attributes for evaluating the MEMS.

pointed out that learning theories strive to lead change in the e-Learning environment. Good learning theories should determine the roles and relationship between the instructor and learner through support by MEMS. Hence, the theories should lead to their proper applications [19]. Besides, they affect users of these theories and it becomes difficult to implement effective strategies for learning [26].

In this paper, four main learning theories, which are the critical theory, activity theory, situated learning and constructivism are elaborated with relation to MEMS so that criteria are also driven from these learning theories.

3.1 Critical Learning Theory (CLT)

Critical learning theory is a social theory oriented toward critiquing and changing society as a whole [20]. Several generations of philosophers and social theorists have contributed to the development of critical learning theory, for example, Max Horkheimer, Theodor Adorno, Herbert Marcuse, Leo Lowenthal, Erich Fromm and Pierre Bourdieu [20].

A theory is critical to the extent that it seeks human emancipation, "to liberate human beings from the circumstances that enslave them" [20]. Critical theory is a useful vehicle for illuminating the ways that we can use emotions both to recreate and to change social structures in any type of classroom [20][10]. Emotion, as a social phenomenon, can be the object of study in a critical classroom. Exploring the factors of emotion and power in society are significant topics for critical theorists. The application of critical pedagogy in a classroom elicits a host of emotions for both learners and educators.

A primary goal of critical theorists is to empower the oppressed to transform the inequalities and injustices inherent in current social systems and structures [26]. Recognizing the ways emotions are used to reproduce and change social structures is fundamental to critical learning theory [10]. The application of critical theory to learning experience is about engaging in emotional reflection, finding the joy of learning and creating the satisfaction of freedom [26].

Therefore, MEMS should be designed to take into cognizance the users so that they will be able to express freely their feeling and emotions. MEMS should provide a dialogue between the instructor and learners as well as learners themselves. Feedback should also be provided with easy at any time. The criteria drawn from the CLT should look at the users and how they feel on the MEMS.

3.2 Activity Learning Theory (AT)

It represents one of the most influential learning practices dating back to the time of Marx and Engels [10]. AT emphasises that learning and teaching are embedded in historical, social and material contexts [7] constituted through practice. It is a new approach to learning where learning by expanding is emerging in the e-learning environments being facilitated by MEMS. Hence, learning is an integral part of an activity, where activity constitutes societal practice [7]. The formulation of AT is the object-oriented practical activity that transforms the consciousness as well as the social and material reality. Concerning MEMS, the object-oriented activities are the activities users (learners and instructors) do through the use of MEMS such as assignments, tests, discussion forums and chats. Goals are pursued within the social and material arrangements. Objects according to [7] and [34] refer to the process of transforming material things to satisfy a certain motive such as acquiring or gaining scores in assignments.

Semiotic and artifacts mediate activity and in this case, are provided by MEMS through the design interface. Hence MEMS are taken as ideal tools for providing learning in the modern world of e-Learning. According to [7], the experience of other people using MEMS-based tool are accumulated in the structural properties of that tool as well as in knowledge about how the tool should be used. Therefore MEMS can act as a mediator that controls how learning should be done using some set of rules. According to [9], all this constitutes an activity system where practice refers to how activity systems evolve and change historically. Thus, learning is conceived as transformations of activity systems including its various components over time.

It, therefore, follows that for effective usability testing and evaluation of MEMS, criteria must look at the tools that are used and the historical and social context of users. The design should look at the activities provided, the feedback and forums provided.

3.3 Situated Learning Theory (SLT)

Situated learning theory is an instructional approach developed by Jean Lave and Etienne Wenger in the early 1990s, and follows the work of [7] and [25]. Anderson et al. [5] claimed that students are more inclined to learn by actively participating in the learning experience and are actively involved in addressing real-world problems. SLT states that there should be a bridge that gives the gap between the theoretical learning done in classrooms to knowledge application in the real world situation [25]. According to [4], situated learning sees learning as contextual where learning will occur if it is embedded in the social and physical context. This can be facilitated by MEMs. As the practice implies, the student is "situated" in the learning experience and knowledge acquisition becomes a part of the learning activity, its context, and the "culture in which it is developed and used" [7]. Students form or "construct" their knowledge from experiences they bring to the learning situation; the success of situated learning experiences rely on social interaction and kinesthetic activity [27].

According to [31], within a community of practice, the learner is considered to be a participant. Learning occurs by a process similar to an apprenticeship called legitimate peripheral participation (LPP) which is from the boundary. The learner then moves from the role of the observer, where the learning and cultural increase to the role of a fully functional agent. Hence, the whole community view and identify the presence of the learner. Therefore, at first, the learner participates from a peripheral point then gradually becomes fully a participant within that community. The essence of LPP is that learning takes place within the community where the knowledge is used, as opposed to learning in conventional schools that teach knowledge that is decontextualized [17]. Situated learning essentially is a matter of creating meaning from the real activities of daily living where learning occurs relative to the teaching environment [29].

The criterion drawn from the situated learning reveals that the development and implementation of MEMS should incorporate the learning experience of users so that they will be able to actively participate in their learning. Learning should be embedded in the social and physical context, hence MEMS should enrich the construction of knowledge by users. The social patterns of users should be embraced through the use of social networks that can be incorporated into MEMS. From the LPP, criterion drawn from such learning practice equip learners to learn as a community where MEMS provides the platform for the group activities. Therefore, usability testing and evaluation of MEMS should look at the different users and their social behavior.

3.4 Constructivism

The constructivism school of learning suggests that learners construct personal knowledge based on learner's prior experience [19]. Learning is seen as an active process, and knowledge cannot be received from outside or someone else but is constructed from the head and ensures learning among learners [23]. Learners should be allowed to construct knowledge rather than being equipped with knowledge through instructions. It also involves situated learning, which sees learning as contextual and suggests strategies promoting multi-contextual learning to make sure that learners can learn to apply the information broadly.

The teacher's role is not only to observe and assess the learning pattern but to be involved by engaging with students in their activities by posing questions for the promotion of reasoning [4]. Learning is taken as an adaptive activity and situated in the context in which it occurs [32][33]. The learners are rather active than passive while instructors play the role of a facilitator. Knowledge is constructed by the learner who also deals with resistance to change [23].

Experiences, background and social interactions play a role in the learning process. Learners are kept active in high-level activities such as asking learners to apply information in practical situations they encounter or discussing a topic within groups. Hence, learners arrive at their version of truth [4] influenced by their background and culture.

Tutorials and drills construction which are proponents of objectivism are regarded as poor in constructivism because they are regarded as not transferable [19][26]. However, methodologies like hypermedia, simulation, virtual reality and open-ended learning environments are of more benefit to learners. Learners use the software as a resource rather than teachers [26]. The design aspects of MEMS need to encompass the constructivism approach to learning so that learners have high interests and a positive feel by users is beneficial.

Criteria for usability testing and evaluation of MEMS drawn from the constructivism approach should focus on user experiences, their background and social interaction. Evaluation should also look at the cultural aspects. The design and implementation of MEMS should provide feedback and equip users with their social patterns. It is then recommended that MEMS, besides providing the learning environment should incorporate social networks so that users embrace them. Having looked at the MEMS design aspects and the four learning theories above, criteria for usability and evaluation of MEMS in higher education were drawn from them. The next section looks at the criteria.

3.5 Criteria for Usability Testing and Evaluation of MEMS from the Learning Theories

Table 2 below shows the three criteria drawn from the design component, one from the user background and one from the institutional.

MEMSD1, MEMSD2 and MEMS D3 are criteria drawn from the design aspects that are needed when designing MEMS. MEMS should provide interaction and feedback with good navigation [43][54][39]. Availability, connectivity and supported functions are system perspectives of MEMS that should be available for user satisfaction [43][54].

The design aspects looked at the user background MEMSUB criterion. This looks at the social pattern and history of users [9]. If MEMS are designed without taking into consideration the social pattern, user background and history it tends to deter users whilst easy to use MEMS that are in line with the learner's skills attract users [2].

Institutional dimensions, MEMSIP criterion also play a significant role in the design and use of MEMS. These include the financial roles and funds availed to the design and implementation of MEMS or the acquisition of it [39]. Institutions are now regarding MEMS as a learning breakthrough and a competitive advantage in this technology-driven world [37]. Under the institutional dimension, the time effect and getting the necessary skilled manpower should be taken into consideration.

From the criteria above, usability testing and evaluation of MEMS is done in three aspects or stages. The stages are not standalone but sometimes concurrently work together. The first stage is before the design and implementation of the MEMS (institutional) where the administrators look at the return of investment and the competitive advantage of having MEMS. Hence, evaluation should look at these aspects from the administrative perspective.

The second is the design and implementation stage. The criteria are drawn from the usability testing and evaluation of MEMS (design component) need to look at how interaction, feedback, navigation, functionality and design interface are supported. Evaluation and testing are done by expert evaluators. The three criteria derived can be used. The last stage involves the user upon having used and experience on the system. Availability, accessibility, connectivity, supported formats and learning standards are critical criteria for usability testing and evaluation of MEMS at this stage. User perception of these critical aspects will be the key drivers for the evaluation and testing.

Having discussed the design aspect, user background and institutional criteria, the next table explains the criteria from the learning theories.

From Table 3, the learning theories deduced each, three criteria for usability testing and evaluation while constructivism came up with five criteria. Criteria CLT1, CLT2 and CLT3 explain the role of the learner in the learning environment Dialogue between the learners themselves and with the instructor is essential [10][26]. Learners use their day to day experience and should express themselves freely their feelings and emotions [20][26].

Criteria AT1, AT2 and AT3 came from the activity theory. The criteria emphasise the need to look at the tools used in learning and how the tools fit with the MEMS design [7]. A look at the user's historical and social background and skills is vital to learning through MEMS [9].

SLT1, SLT2 and SLT3 look at learning being contextual [4]. Students form or "construct" their own knowledge from experiences they bring to the learning situation through social networks [7]. Learning should be embedded in the social and physical context [31], hence MEMS should enrich the construction of knowledge by users which improves individual performance [27][29].

CV1, CV2, CV3, CV4 and CV5 are criteria drawn from the constructivism. In all these criteria, focus on user experiences, their background and social interaction is essential [4][19]. Knowledge is constructed by the learner who also deals with resistance to change [23]. MEMS designed and implemented that take the constructivism approach should equip learners than the instructors [23][26].

The design and implementation of MEMS must incorporate the above learning theories so that usability testing and evaluation are received by users. The criteria also fit well on stage three, where evaluation and testing should look at how knowledge was constructed, activities administered, cooperation and collaboration enhanced, learner and instructor experience, and finally

Table 2: Criteria for usability and evaluation of MEMS drawn from the design aspects and institutional dimensions

Criteria	Criteria Number	Explanation
Design	Criterion MEMS D1	Content and qualityaspects of MEMS are determined by navigation, feedback, interaction,functionality and design interfacetowards user satisfaction.
	Criterion MEMS D2	Adaptable MEMS arenot going to be determined by pedagogical aspects but by the availability,accessibility and user background that includes training.
	Criterion MEMS D3	Connectivity, availability,technical, available functions, supported formats, learning standards and recovering standards are the key variablesfor testing and evaluation from the system perspective.
User background	Criterion MEMS UB	User background andhistory, training and support, communication and collaboration, interaction andnavigation, behaviour, satisfaction and perception are the key variables fortesting and evaluating usability from the user perspective.
Institutional	Criterion MEMS IP	Cost and return ofinvestments are the key variables for usability testing and evaluation from theadministrative perspective.

the user history and perceptions. This fit also in disaster scenarios where learners are more fully going to online and distance learning like the COVID 19 situation.

Derived criteria (see Table 2 and 3) are interrelated and when combined they, reflect how an integrated framework for usability testing and evaluation of MEMS by users should appear. The evaluation of MEMS against the identified criteria might inform its relevance for practice and will most probably contribute to its refinement as well.

However, the authors believe that some practice-based research is necessary to complement the theoretical perspective of the criteria drawn above. Hence, a usability testing and evaluation based on these criteria was done on an improved MEMS called at TSIME at the University of Zimbabwe.

4 Methodology

The study looked at usability testing and evaluation of a MEMS called Towards Student-Centred Integration of Multimedia ELearning, TSIME that was used at the University of Zimbabwe.

4.1 Features on Current TSIME

The TSIME platform is a learning management system customised from the open-source system Claroline. It has the common features for user login, creating accounts and management of courses like all other MEMS used in higher education. This includes the creation and registration of users, creation of courses by lecturers as well as enrolment by students for particular courses. Figure 1, Figure 2 and Figure 3 present the TSIME system.

Upon login or creating an account, the desktop platform appears where course creation or enrolment can be done. Also one can view the latest announcements and messages See Figure 2. When the lecturer or student selects a course, there are features like announcements, exercises and create users as in Figure 3.

However, most of the multimedia design attributes that consist of text, images and other features from the above figure were not changed hence remained the same. As explained in the above sections, the main critical component for MEMS is the design interface, interaction and feedback and content.

Improvement of TSIME involved integrating a SNS that was not available. The TSIME platform was a customised MEMS from the open-source system Claroline and was integrated with another open-source mobile application Mahara (a Social Networking Site or Service) for social networking. They were incorporated using a Single Sign-On (SSO) from one platform that gave ease of access to users. By using SNS, users had an extra channel to communicate uninhibitedly and to access an extensive variety of data which helped them in their learning [30]. The SNS supported collaboration among users where connections in SNSs were done through posting and remarking on messages, pictures and recordings about user profiles that are associated. Mahara gives users/clients the same number of views that each user enjoyed [39], hence, students and instructors fully benefited from the integration of the SNS.

The study then used the HE method for usability

Table 3: TSIME Usability Heuristics (TSIMEUH) with explanations

Criteria (Learning theories)	Criteria Number	Explanation
Critical Theory of Learning	Criterion MEMS CLT1	Learning involves a dialogue between learners and instructors facilitated by MEMS through observation, discussion forums and interviews
	Criterion MEMS CLT2	Learners are not dormant but critically challenges given and laid assumptions
	Criterion MEMS CLT3	Learners use their day to day experience to reflect and guide the discussions which should finally lead to change through emotions
Activity Theory	Criterion MEMS AT1	The learning and teaching are embedded in the historical, social and material context done through practice
	Criterion MEMS AT2	Learners and instructors use knowledge and experience of other users about tools (MEMS) which accumulates in usage
	Criterion MEMS AT3	On MEMS usage rules are set and the practice requires that activity systems evolve and change
Situated Learning	Criterion MEMS SLT1	Learners should be exposed to their instructors though instructors play a peripheral role in the whole learning and MEMS should provide and promote a constructive learning culture
	Criterion MEMS SLT2	MEMS should improve individual performance through social interaction with peers through their daily experiences and real activities (usable knowledge is gained through the environment)
	Criterion MEMS SLT3	MEMS should manage and give better students perception and a positive attitude to learning by providing sophisticated problem-solving skills based on situated learning.
Constructivism	Criterion MEMS CV1	Instructors should provide good interaction and give learners a control in their learning through proper usage of MEMS
	Criterion MEMS CV2	Learning is taken as an adaptable activity and situated in the context it occurs through the provision of good multimedia content by instructors by giving illustrative examples and cases of theoretical formations with the use of MEMS.
	Criterion MEMS CV3	Knowledge is constructed by the learner and learning should then be meaningful that deals with resistance to change through the development of new skills, knowledge and attitude.
	Criterion MEMS CV4	Learners use the software as a resource and emphasise the use of a computer for constructive communication through e-mail, internet chat rooms, video conferencing and file sharing.
	MEMS CV5	Instructors should provide interactive learning activities for the learners and these are solved through collaboration and cooperation among learners.

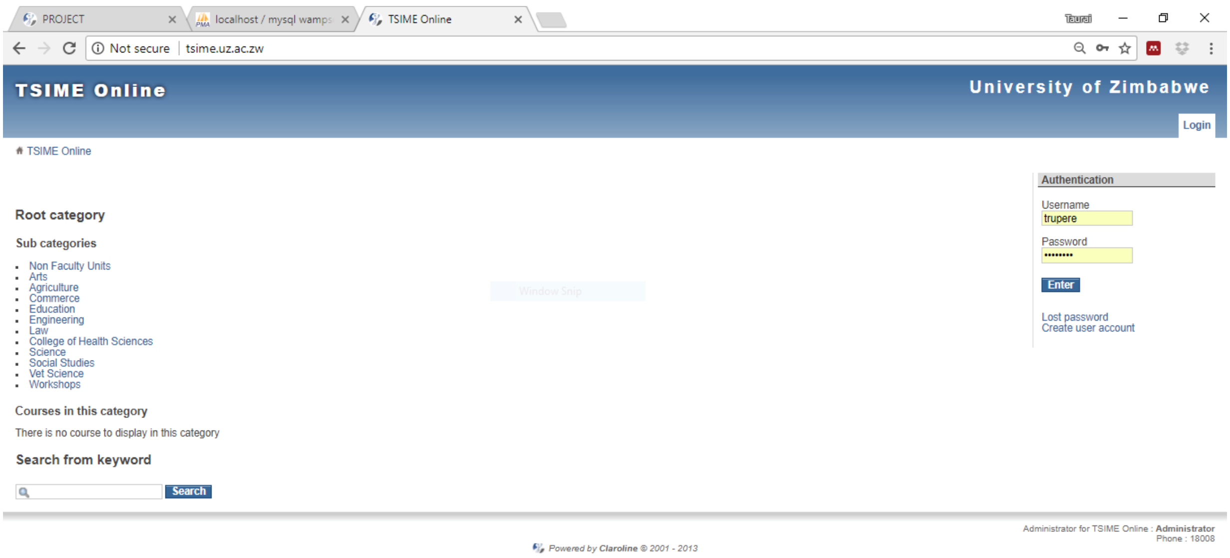

Figure 1: User login page

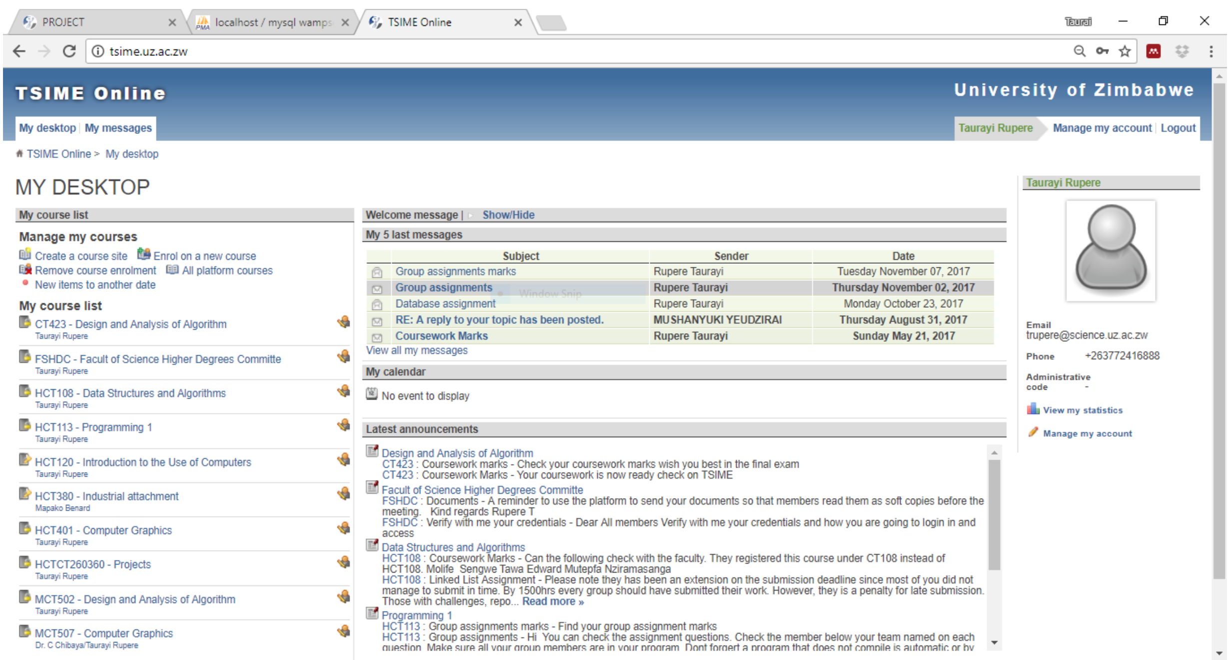

Figure 2: Lecturer TSIME desktop

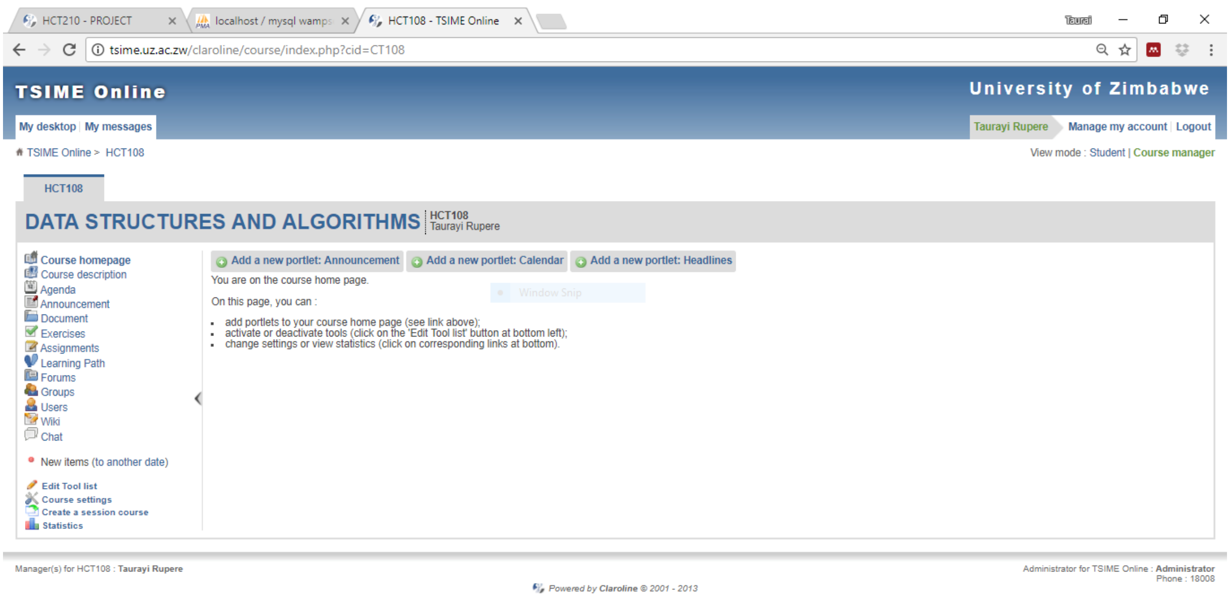

Figure 3: Course features

testing and evaluation. HE [54][50][40][38] is a popular and an informal UEM that uses experts [6]. It is an inspection method that examines software features, in this case, TSIME features for potential causes of poor usability. The evaluator skills and expertise, as well as experience, determine the final output. Small groups of evaluators are needed at least two evaluators and individually inspect the system [50]. Zaharias and Koutsabasis [56] postulated that HE involves experts evaluating the user interface [15]. The experts lay out some guidelines and principles for good design. HE is a UEM that is less costly and a better predictor of a problem because it identifies many usability problems [4]. It relies mainly on judgment on the system by expert inspectors evaluating an interface against a set of heuristics. HE is popular because it is fast and inexpensive and relatively easy to implement [42].

In this study, three experts [28] were drawn from the education and computing departments as well as the development team at the University of Zimbabwe. Their domain expertise was from the teaching aspect (education), the software and implementation aspect (computing department) and lastly the system development aspect (development team). Usability guidelines called heuristics were drawn by the experts to assess the extent to which TSIME design and interface components conform to the guidelines. The evaluators were not allowed to communicate and integrate the results of their evaluations to ensure the independent and unbiasedness of the evaluation. The Nielson [46] ten heuristics that have been extended by Squires and Preece [52], Preece et al. [45] have been generally been accepted and used for evaluation. The heuristics can be applied at different stages of system development.

The heuristics in this study were drawn from the criteria explained in the literature review section. Some heuristics were merged with the generic heuristics done by [19][42][38][52][6]. The heuristics are outlined in the next section. The three expert evaluators took about 2 weeks to carry out the HE on TSIME using the laid down criteria above.

Each inspector evaluated the system independently [13] by working through more than once and evaluating it at each pass. The problems that were identified were then listed according to the severity and the heuristics that will have been violated. The validity of the TSIME set of heuristics, HE of multimedia additions and the general interface on TSIME was done. Also, since the Nielson heuristic [46] have been evaluated in different e-learning environments and the other heuristics it was sufficient enough to validate the set of heuristics.

5 Usability Texting and Evaluation from Experts Perspective

This section provides the HE done on TSIME.

Table 4: TSIME Usability Heuristics (TSIMEUH) with explanations

No	TSIME Usability Heuristic	Explanations
1	Interactivity	Users are engaged in interactive multimedia eLearning programs
		Users respond to the multimedia programs and the programs give user activity
		Users have confidence in the multimedia environment and interact perfectly with the way the multimedia elements are designed
2	Motivation to learn	The multimedia components stimulate the learning process
		The learning gains attention and maintains the motivation of users
		Learning is enjoyable and interesting
		Actions are viewed by text, audio, video and animations
3	Content design	The terminology is appropriate for users
		The organisation of multimedia contents is suitable for the users
		The style is appropriate to the users
4	Assessment	Assessment both individual and group is included
		There is appropriate feedback on the platform
5	Design attractive and intuitive screen layouts	Screen layouts are visually pleasing and efficient
		The font choice, colour and sizes are consistent
		Screen designs are simple, not cluttered but readable and memorable
		Position elements on the screen are easily perceived, attractive and understandable
6	Accessibility	TSIME can be used on a variety of equipment and platforms such as PDA, laptops
		TSIME can be accessed with both web and mobile information and platform
7	Visibility of System Status	TSIME keeps users informed through timely and appropriate feedback
		Users always know where they are, the actions they can take and how the actions are performed
		Users understand the terminology used on TSIME
8	The match between TSIME and real world	TSIME interface employs familiar words, phrases and concepts to the users
		Follow real-world conventions making information appear in a natural and logical order
		Multimedia learning objects are recognised and understandable by users
		TSIME holds principles of multimedia learning
9	Consistent and Conformity to standards	TSIME uses commonly accepted software and platform conventions
		TSIME conforms to user expectations
		TSIME is consistent in its use of different words, situations, or actions
10	User control and freedom	Users can control the direction and pace of TSIME
		Close and exit are marked in case of users taking the wrong mistake
		Navigation tools and objects are kept in particular and clearly defined positions
11	Help and documentation	TSIME can be used without documentation
		If needed help and documentation should be concise and easy to search
12	Flexibility and efficiency of use	Users can modify TSIME to suit individual capability and needs
		Learning objectives should be balanced with different ways of learning
13	Error prevention and tolerance	There should be careful design to prevent errors occurring
		TSIME does not allow the users to make irreversible errors
		TSIME is designed to offer a second chance when an unexpected input occurs
14	Users recognise and recover from errors	Errors messages are expressed in plain language that does not include grammar code, precisely indicate the problem in a friendly way and suggest a solution that a user can handle
15	Aesthetic and minimalist design	No irrelevant information as it competes with relevant information
		The screen interface does not contain irrelevant information or rarely needed in a multimedia e-learning program
		Animation and transitions should be used sparingly
16	Minimise memory load; recognition rather than recall	TSIME make objects, actions and options visible
		Instructions for use of TSIME are visible or easily retrievable so that users do not have to memorise unnecessary things
		Icons and other screen elements are intuitive and self-explanatory
		Navigation is consistent and logical

5.1 TSIME Usability Heuristics Criteria (TSIMEUH) Design

Sixteen heuristics came from the criteria drawn from Tables 1,2 and 3 with some merged with the generic heuristics by [19][42][38][52][53][6]. The following table lists the TSIMEUH and their explanations.

The first six heuristics (1 to 6) were the researcher of this study defined heuristics see Table 4). Heuristics from number seven to sixteen were merged and adopted from the ten Nielson [42] usability heuristics. The detailed explanation helped the usability evaluators (expert evaluators) to directly apply the heuristic while evaluating TSIME.

5.2 HE Procedure (TSIME HE)

The three evaluators or experts focused on how each heuristic was satisfied or violated. Finally, TSIME problems were defined. For each predicted problem, the experts were supposed to explain how severe the problem was and also to suggest possible or alternative solutions to resolve the issues [50].

The three expert evaluators took about 2 weeks to carry out the HE on TSIME using the laid down criteria above. Each expert was given a link to the site and worked independently. Before working on the evaluation, instructions were clearly outlined on the purpose, which was to improve TSIME.

A template was designed for recording and grading the common problems encountered. The expert evaluators went over the whole system using the heuristics in the table above. In addition, experts were also allowed to record their opinions by indicating the heuristics that were relevant for each problem and then assign severity scores based on impact, frequency and persistence. This was given on the form as a comment in line with each heuristic. The Nielson [42] severity rating scale was adapted and used ranging from 1 to 4 as shown in Table 5.

Finally, each expert was expected to submit the results with a short report based on the template. The problems identified were cataloged and categorised according to the impact rate, the heuristics involved and the sections of the interface elements. The grouping was done where scale groups 3 and 4 were put in one category and deemed very serious while 1 and 2 were regarded as not much serious.

5.3 Results of the Heuritics Evalution

The expert evaluators submitted results after two weeks. The experts are shown as E1 for the first expert, E2 for second expert and E3 for the final third expert (see Table 6 und 7).

A total of 28 usability problems were identified as shown in Table 6. Of these usability problems, 10 were in category 3 and 4 that needed high priority. Training of users was the major concern that was highlighted by all evaluators. Instructors (lecturers) were encouraged to use the platform. Usage would then cascade to the students. The issue of improved hardware was raised by all evaluators. The institution was recommended to acquire or improved hardware that would enable multimedia audio and video streaming. The other usability problem that needed high attention was the navigation buttons that were raised by one evaluator.

The rest of the usability problems were in categories 1 and 2 which needed low attention and generally were of design issues that were mostly fixed. The system was set to be used by users so that user testing would be done.

6 Discussion of Findings

The section discusses the criteria based on the key research questions that emanated from the first section and the results from the HE study.

The study came up with the usability heuristics on the institutional dimension and design aspects of MEMS. The design aspects of MEMS were used to draw up the heuristics for HE, with some merged with the generic heuristics. Usability testing and evaluation of MEMS took criteria from the design aspects of MEMS (MEMSD1), the learners' perspective and the instructor's perspective. The other deduced criteria (MEMS D2 and MEMSD3) showed that MEMS should provide good navigation control for users, providing good feedback and interaction. MEMS that provide poor interaction and functionality to users tend to give negative user satisfaction. Hence, MEMS testing and evaluation should consider the design aspects which affect the learning process. The generic heuristic from [19] [42] [38] [51] [53] and [6], though proven to work for HE, this study showed that there are other essential additional heuristics from the design aspect. Any evaluation and testing method that lacks these design criteria is deemed not to reflect the usability of MEMS. However, though the design aspects and learning theories are essential in testing and evaluation, institutions in higher education sometimes overlook these aspects, looking at costs versus return on investments (MEMS IP).

The evaluators pointed out the need for improved hardware. This aspect needs institutional criteria. The results showed that the cost and return of value are determined by these criteria as alluded by [8]. High connectivity is needed with bigger bandwidth so that users get the full functionalities provided by MEMS.

Table 5: A severity rating scale for heuristic usability (adapted from [42])

Scale Group	Impact	Explanation
1	It is a superficial, cosmetic problem	It need not necessarily be fixed
2	Minor usability problem	Fixing this should be a low priority
3	Major usability problem	Fixing this should be a high priority
4	Usability catastrophe that causes failure	Must be fixed before the system is used by users

In some instances, the licensing requires more costs. The costs sometimes increase when hiring experts to design, develop and implement the MEMS. Hence, administrators of institutions view the usage of MEMS from a different perspective to the users' and developers' point of view. Usability testing and evaluation of MEMS should look at the institutional dimension.

One critical attribute that evaluators pointed out was the need for improved motivation and ethics. The solution dwells on the need for training and familiarization with the platform. Although MEMS have shown to provide a better interface between users and their learning environment and patterns, as well as offering good navigation (Table 6), results show a need to look at the history and background of users (MEMS UB). This helps in identifying the best approaches that can be used and undertake in training and support. Availability, connectivity, technical and support formats of MEMS (MEMS D3) also need to be in place to test and evaluate how MEMS are used in higher education from the system perspective. Any testing and evaluation of MEMS should look at how the system incorporates these aspects. The same results were highlighted by the study [35]. The motivation aspect was determined by cognitive thinking and positive emotions. This happens in situated learning and criterion MEMS SLT2 determines the role of positive attitude from both the learners and instructors.

Results from the study also showed that both sets of evaluators pointed out the safety and security concerns on the platform. This points to the lack of proper integration of SNS within the MEMS framework (MEMS SLTs, MEMS ATs, and MEMS CLTs). The history of users, their social behavior and background can be traced and used in the usability testing and evaluation of MEMS. Users enjoy using MEMS that embrace their social patterns.

Behavior and motivation can be tested using user perceptions after users had used the system rather than the system perception. Therefore, the study showed that theories embrace the consolidated learning where there is feedback, interaction, knowledge creation and construction, user experience and collaboration among users. In addition to background, the learners' day to day experience is critical so that it reflects the experiences of users in their critical learning. As also pointed out by Elbitar [16], user experience should be in line with the experience in technological use. Hence, a critical and constructivism approach to learning can be followed by taking some aspects of situated learning (MEMS CVs). Using the constructivism learning theory, testing and evaluation criteria can be used in drawing up the aesthetic and minimal design usability heuristics.

The learning pattern, though embedded in the historical, social and material context, should be improved through interaction and feedback provided by MEMS. Thus, learning is viewed (activity theory) as a transformation of activity systems and various components that are provided by MEMS over a period of time (MEMS ATs). The learners should be able to construct knowledge and develop new skills independent of the instructor. Hence, the situated learning environment where the learners learn from their instructors is however not the ideal solution but that instructors should play a leading role though not fully involved in the learners' activities (MEMS SLTs). As one evaluator pointed out that for students to be motivated, it should start from the instructors then cascade to learners. There should be a dialogue among learners and instructors empowered through MEMS environments. Bervell and Umar [10] showed the need to equip the instructors on multimedia e-learning through training. This helps to empower learners. The courseware provided through MEMS becomes the learning environment that supports various support activities through different multimedia contents. Thus, usable knowledge is gained through environments.

The situated and constructivism learning theories provide support through cooperation and collaboration with learners. The critical learning approach provides the support dialogue, hence when there is dialogue, there is collaboration and cooperation among learners and instructors. Situated learning requires expert performance which lacks on the constructivism. With these criteria, learners are equipped with relevant knowledge and skills that take into consideration their background and learning history. If the institutions of higher education take into consideration the learning in line with the user needs, design, development and evaluating MEMS will empower learners in their learning environments.

Table 6: Usability problems detected by heuristic evaluators

Attribute	Heuristic Involved	Interface Element	Usability Problem	Scale Impact	Solution
Design Interface	Content design	Multimedia contents (video, audio, text, images, animations)	E1: Video, text and images appropriate Less animation	2	Streaming needs more hardware requirements hence acquire more streaming hardware
			E2: Multimedia content is good but needs more interactive	2	Add more tools for interaction
			E3: Video and images are fine but should provide more feedback	2	Direct feedback when multimedia contents are streamed
	Design attractive and intuitive screen layouts	Screen layouts, position, font and readability	E1: Font can be improved to be consistent throughout	2	Use standard font throughout from the initial login page to other pages
			E2: Readability of some text on windows should be improved	2	Improve readability on some windows
			E3: Check the positioning of some images and font	2	Position well the screen images
	Consistent and Conformity to standards	User expectations, consistent in its use of different words, situations or actions	E1: Improve readability on some text	2	Readability Improved
			E2: Should be able to increase the font size	2	Font increase and reduction implemented
			E3: Ability to increase and reduce font on the browser	2	Font increase and reduction implemented
	Aesthetic and minimalist design	No irrelevant information. Animations and transitions should minimally be used	E1: Remove redundant and repetitive text on the screen for images	1	Redundant text removed
			E2: Few animations and transitions	1	Correct as it is
			E3: No animations and transitions	1	The system is good as it is
Interaction and Feedback	Interactivity	Programs give user activities and interact perfectly with users	E1: Good interaction	1	There is interaction though more can be done with improved hardware
			E2: Less interaction	3	Improve interaction by having big hardware storage
			E3: User activities are given properly	1	More group activities
	Help and documentation	Provide help and documentation	E1: Search facility present	2	Put the FAQ as a help guide
			E2: The help should be precise	1	Search facility available
			E3: Provide documentation	2	Codes and algorithm for the system availed
	Help users recognise, dragonise and recover from errors	Errors messages are expressed in plain language that does not include grammar code	E1: Fewer error messages popping on the system	1	Error messages expressed in plain language
			E2: Error message are clearly stated	1	Error messages are clearly expressed
			E3: Error messages fit the browser requirement	1	Good error messages outline

Table 7: Usability problems detected by heuristic evaluators (Continuation of Table 6)

Attribute	Heuristic Involved	Interface Element	Usability Problem	Scale Impact	Solution
Navigation	User control and freedom	Good navigation	E1: Navigation links present and clearly laid out	1	Could put links on the stop, pause and continue on video scene play
			E2: No dead pages	1	Pages are well linked
			E3: Navigation is good throughout	1	Hyperlinks are clearly laid out.
	Assessment	Individual and group assessment	E1: Ability to assess both individual and group	1	Students can be assessed with easy
			E2: Assessment set up for individual and groups	3	Improve on mobile and social aspects
			E3: Group and individual assessment	1	Assessment is good
Motivation And ethics	Motivation to Learn	Will users be motivated with the platform	E1: User motivation	3	Training and familiarisation with the platform is needed
			E2: Motivation with system	4	The more the instructors use the system the more the motivation by students
			E3: High usage of the platform by users	3	Training and promotion of TSIME is needed
	The match between TSIME and real world	Multimedia objects are recognised. Match with the real world reality	E1: Update the information on the image and audio window set up	2	Objects on image and audio updated
			E2: Modify the text on images and audio	3	Modify some sections on multimedia windows
			E3: Update the statistics section	2	Statistics section updated
Accessibility	Accessibility	Support various equipment like PDAs, phones and Laptops	E1: Different gadgets are supported	2	Improve on Wi-Fi and general connection
			E2: Connectivity issue	2	Users can connect everywhere
			E3: Connectivity and accessibility	2	Improve Wi-Fi connectivity
	Minimise memory load; recognition rather than recall	make objects, actions and options visible	E1: Icons and other screen elements are intuitive and self-explanatory	2	Improve on icons on certain pages
			E2: Visibility on video streaming	3	Streaming is improved for mobile applications
			E3: Navigation is consistent and logical	2	Improve navigation on the back and forward buttons
	Safety and security to both web and mobile users	System secure to hackers and intruders	E1. Security is guaranteed to both and web applications	3	Improve the security to mobile clients
			E2. Assessment set using both web and mobile devices	3	Improve on the multimedia components
			E3. Few multimedia downloads on mobile apps	3	Reduce videos and animations on mobile

The heuristics developed in this study extended the generic heuristics that had been used by various authors. These heuristics can now work as an evaluation framework for different MEMS, as they have been validated and developed from the usability attributes and learning theories. Finally, if these criteria are fully embraced from all the three usability and evaluation stages, the framework will play a major role in multimedia e-Learning environments. Hence an integrated testing and evaluation framework would be in place for higher educational institutions.

7 Conclusion and Recommendations

7.1 Implication for Theory

Results from the usability testing and evaluation from the three experts using the researcher TSIME HE criteria showed priorities that needed attention on the MEMS. High priority attention focused on the motivation and ethics attribute which had all the three expert evaluators' flagging. The results reflect the challenges encountered in the global pandemic such as the COVID-19 era where learning is now offered at home through MEMS. The need for motivation and ethics was pointed and therefore should be incorporated in the MEMS design and implementation. Results also showed that if users are not motivated they do not use the MEMS. Motivation must start from the instructors then should cascade to students. Lack of motivation may be due to lack of training on how to use MEMS. Therefore, users need to be trained first on how to use the MEMS. Design quality, accessibility and interaction attributes needed low to medium intervention. Accessibility issues centered on the hardware and networking features not necessarily on the system itself. The institutional dimension of resource acquisition and financial effect comes to effect. Services offered to users like Internet access and infrastructure depend on the budget offered by institutions on these services. This affects the system where multiple multimedia streaming may require bigger bandwidth thus affecting accessibility. From a theoretical and practical rationale, results suggest that the criteria are widely applicable. Conclusive evidence needs to be determined by having many experiments in multimedia e-learning academic environments on the usability of various MEMS from the system and user perspective.

7.2 Recommendation for Practice

The derivation of criteria for usability testing and evaluation of MEMS revealed new paths to learning in HE environments as well as the global pandemic such as COVID-19. The results strongly support the following general arguments and conclusions: Usability testing and evaluation of MEMS in higher education involve different criteria. The criteria are drawn from the institutional dimension, MEMS design (system), learning theories and finally the MEMS usability (users). On how the criteria empower learning in multimedia e-Learning environments, it is through the learning theories that should be incorporated into the design and implementation stage. The learning theories should allow the learner to be in control and be involved in their learning with collaboration and corporation among themselves. The global pandemic like COVID-19 now confines learners to their homes. Therefore, the criteria should equip learners to have control of their learning. Training should be provided to equip users on how to use the system. The instructor plays a peripheral role. Such an approach allows learners to use their background and social experience. They can interact, create knowledge and develop skills with easy. The integration of these criteria formulates a usability testing and evaluation framework of MEMS in higher education. Hence the key findings show that there is a crucial role to be played by the institutional dimension, MEMS development and user evaluation for MEMS.

7.3 Recommendation for Further Study

The study recommends that the derived criteria be used in the user evaluation to determine the perception and attitude of the learners and instructors. Hence, a consolidated integrated usability testing and evaluation framework for MEMS from system, administrators and users can then be derived.

7.4 Limitation of the Study

The study was limited to HE of MEMS. Other usability testing and evaluation like Cognitive Walkthrough (CW), Think Aloud (TA) still need to be carried to see if the criteria are applicable.

Acknowledgment

The study acknowledges the University of Zimbabwe for giving ahead to the study and the evaluators who participated in the study.

References

[1] A. Abran, A. Khelifi, W. Suryn, and A. Seffah, "Usability meanings and interpretations in ISO standards," Software Quality Control, vol. 11, no. 4, pp.325–338, 2003.

[2] I. A. Almarashdeh, N. Sahari, and N. A. M. Zin, "Heuristic evaluation of distance learning management system interface," in Proceedings of International Conference on Electrical Engineering and Informatics, ICEEI 2011 Bandung, Indonesia, pp. 1–6, 2011.

[3] D. Alonso-Ríos, a. Vázquez-García, E. Mosqueira-Rey, and V. Moret-Bonillo, "Usability: A critical analysis and a taxonomy," International Journal of Human-Computer Interaction, vol. 26, no. 1, pp. 53–74, Dec. 2009.

[4] A. F. Alzaghoul, "The Implication of the learning theories on implementing e-learning courses," Research Bulletin of Jordan ACM, vol. 11, no. 11, pp. 27–30, 2012.

[5] J. R. Anderson, L. M. Reder, and H. A. Simon, "Situated learning and education," Educational Researcher, vol. 25, no. 4, pp. 5–11, 1996.

[6] C. Ardito, M. F. Costabile, M. De Marsico, R. Lanzilotti, S. Levialdi, T. Roselli, and V. Rossano, "An approach to usability evaluation of e-learning applications," Universal Access in the Information Society., vol. 4, no. 3, pp. 270–283, Dec. 2005.

[7] H. C. Arnseth, "Activity theory and situated learning theory: contrasting views of educational practice," Pedagogy Culture and Society Culture., vol. 16, no. 3, pp. 289–302, 2008.

[8] M. Asarbakhsh and J. Sandars, "E-learning: The essential usability perspective," The Clinical Teacher., vol. 10, no.1, pp. 47–50, 2013.

[9] M. Ben-Ari, "Situated learning in computer science education," Computer Science Education, vol. 14, no. 2, pp. 85–100, 2004.

[10] B. Bervell and I. N. Umar, "Utilization decision towards LMS for blended learning in distance education: Modeling the effects of personality factors in exclusivity," Knowledge Management & E-Learning, vol. 10, no. 3, pp. 309– 333, 2018.

[11] A. Blecken, D. Bruggemann, and W. Marx, "Usability evaluation of a learning management system," in System Sciences, (HICSS), 2010 43rd Hawaii International Conference on System Sciences, Honolulu, HI, USA, vol. 1, pp. 1–9, 2010.

[12] L. Carvajal, A. M. Moreno, M. I. Sánchez-Segura, and A. Seffah, "Usability through software design," IEEE Transactions on Software Engineering, vol. 39, no. 11, pp. 1582–1596, 2013.

[13] K. Charmaz, "Constructivist grounded theory," Journal of Positive Psychology, vol. 12, no. 3, pp. 299–300, 2017.

[14] P. K. Chilana, A. J. Ko, J. O. Wobbrock, T. Grossman, and G. Fitzmaurice, "Post-Deployment usability: A survey of current practices," in Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems (CHI 2011), Vancouver, BC: ACM Press, pp. 2243–2246, 2011.

[15] R. St. Clair and J. Sandlin, "Incompetence and intrusion: On the metaphysical use of illiteracy in U.S. political discourse," Adult Basic Education: An Interdisciplinary Journal for Adult Literacy Educational Planning, vol. 14, no.1, pp.45-59, 2004.

[16] M. R. Davids, U. M. E. Chikte, and M. L. Halperin, "An efficient approach to improve the usability of e-learning resources: the role of heuristic evaluation," AJP Advances in Physiology Education, vol. 37, no. 3, pp. 242-248, 2013.

[17] H. M. M. Elbitar, "Egyptian industrial education teachers' perceived computer self-efficacy," International Journal of Vocational and Technical Education, vol. 7, no. 8, pp. 80–88, 2015.

[18] Y. Engeström and V. Glăveanu, "On third generation activity theory: Interview with Yrjö Engeström," European Journal of Psychology, vol. 8, no. 4, pp. 515–518, 2012.

[19] A. Fernandez, E. Insfran, and S. Abrahão, "Usability evaluation methods for the web: A systematic mapping study," Information and Software Technology, vol. 53, no. 8, pp. 789– 817, 2011.

[20] K. Finstad, "Response to commentaries on the usability metric for user experience," Interacting with Computers, vol. 25, pp. 327–330, 2013.

[21] L. L. Freire, P. M. Arezes, and J. C. Campos, "A literature review about usability evaluation methods for e-learning platforms," in Work, vol. 41, supplement. 1, pp. 1038–1044, 2012.

[22] M. A. M. Ghalib and M. Chandrashekara, "Usability: An Approach To Assessing Open Source Elearning Course Ware," SRELS Journal of Information Management, vol. 47, no. 5, pp. 531–536, 2010.

[23] B. Ghirardini, ”E-learning methodologies: A guide for designing and developing e-learning courses,” Food and Agriculture Organization of the United Nations (FAO), 2011.

[24] J. Hafer and A. Kiy, “The university-wide introduction of an ePortfolio system as transdisciplinary task: Results of an implementation process and perspectives on an optimized process model,” in the Conference on Learning and Diversity in the Cities of the Future, pp. 363-373, 2013.

[25] J. Herrington and R. Oliver, “Critical characteristics of situated learning: Implications for the instructional design of multimedia,” in Proceedings of the ASCILITE 95 Conference, pp. 253–262, 1995.

[26] C. Hoadley, “Theories and methods from learning sciences for e-learning”, in Handbook of E-Learning Research, SAGE, pp. 139–156, 2007.

[27] K. Huang, I. A. Lubin, and X. Ge, “Situated learning in an educational technology course for pre-service teachers,” Teaching and Teacher Education, vol. 27, no. 8, pp. 1200–1212, 2011.

[28] W. Hwang and G. Salvendy, “Number of people required for usability evaluation: The 10+/- Rule,” Communications of the ACM, vol. 53, no. 5, pp. 130-133, 2010.

[29] N. z -Illinois, “Situated Learning,” N. Illinois Design Center, 2007.

[30] I. Jahan and S. M. Z. Ahmed, “Students’ perceptions of academic use of social networking sites: A survey of university students in Bangladesh,” Information Development, 2012.

[31] J. Lave and E. Wenger, “Situated learning: Legitimate peripheral participation,” Learning in Doing, vol. 95, 1991.

[32] A. Koohang, “A learner-centered model for blended learning design,” International Journal of Innovation and Learning, vol. 6, no.1, pp. 7691, 2009.

[33] A. Koohang, L. Riley, T. Smith, and J. Schreurs, “E-Learning and constructivism: From theory to application,” Interdisciplinary Journal of ELearning and Learning Objects, vol. 5, no. 1, pp. 91–109, 2009, Retrieved August 1, 2020.

[34] R. Kop and A. Hill, “Connectivism: Learning theory of the future or vestige of the past?,” International Review of Research in Open and Distance Learning, vol. 9, no. 3, pp. 1-9, 2008.

[35] I. A. Korepanova and E. M. Vinogradova, “Understanding A. N. Leontiev’s activity theory: Y. Engeström and his works,” Cultural-Historical Psychology, vol. 4. pp. 74– 78, 2006.

[36] D. Leutner, “Motivation and emotion as mediators in multimedia learning,” Learning with Instructions, vol. 29, pp.174-175, 2014.

[37] G. Lindgaard, “Early traces of usability as a science and as a profession,” Interaction with Computers, vol. 21, no. 5-6, pp. 350–352, 2009.

[38] M. Machado and E. Tao, “Blackboard vs. Moodle: Comparing user experience of learning management systems,” in Proceeding- ASEE/IEEE Frontiers in Education Conference Milwaukee, WI December 2006, pp. 7–12, 2007.

[39] R. Mack and J. Nielsen, “Usability inspection methods,” ACM SIGCHI Bulletin, vol. 25. pp. 28–33, 1993.

[40] M. I. D. P. A. Muniz and A. De Moraes, “Usability issues in Learning Management Systems (LMS),” Work (Reading, Mass.), vol. 41 Supp. 1, pp. 832–837, Jan. 2012.

[41] J. Nielsen, “Usability 101: Introduction to usability why usability is important,” All Usability, pp. 1–69, 2003.

[42] J. Nielsen, ”Usability Engineering,” Morgan Kaufmann, Academic Press Cambridge, MA, 1993.

[43] J. Nielsen, “Usability 101: Introduction to Usability,” Nielsen Norman Group, 2012.

[44] S. Ozkan and R. Koseler, “Multi-dimensional students’ evaluation of e-learning systems in the higher education context: An empirical investigation,” Computers and Education, vol. 53, no. 4, pp. 1285–1296, Dec. 2009.

[45] I. Padayachee, P. Kotzé, and A. Van Der Merwe, “Course management systems from a usability perspective,” Alternation, vol. 18, no. 1, pp. 297–317, 2011.

[46] J. Preece, Y. Rogers, and H. Sharp, Interaction design: beyond human-computer interaction, John Wiley & Sons, New York, 2nd Edition, vol. 11, 2007.

[47] A. Seffah, M. Donyaee, R. B. Kline, and H. K. Padda, "Usability measurement and metrics: A consolidated model," Software Quality Journal, vol. 14, pp. 159–178, 2006.

[48] B. Shackel, "Usability - Context, framework, definition, design and evaluation," Interacting with Computers, vol. 21, no. 5-6, pp. 339–346, 2009.

[49] R. Schnall, S. Bakken, W. B. Iii, A. Carballo-Dieguez, and S. Iribarren, "Usability evaluation of a prototype mobile app for health management for persons living with HIV," Studies in Health Technology and Informatics, vol. 225, pp. 481-485, 2016.

[50] S. Ssemugabi and M. De Villiers, "Effectiveness of heuristic evaluation in usability evaluation of e-learning applications in higher education," South African Computer Journal, vol.45, no. 45, pp. 26–39, July 2010.

[51] T. Spiliotopoulos, P. Papadopoulou, D. Martakos, and G. Kouroupetroglou, "Integrating Usability Engineering for Designing the Web Experience: Methodologies and Principles," Information Science Publishing Press, IGI Global, 2010.

[52] D. Squires and J. Preece, "Predicting quality in educational software: Evaluating for learning, usability and the synergy between them," Interacting with Computers, vol. 11, no. 5, pp. 467–483, 1999.

[53] D. Sy, "Adapting usability Investigations for agile user-centered design," Journal of Usability Studies, vol. 2, no. 3, pp. 112-132, 2007.

[54] Z. Unal and A. Unal, "Evaluating and comparing the usability of web-based course management systems," Journal of Information Technology Education: Research, vol. 10, no. 1, pp. 19-38.

[55] V. C. X. Wang, "Understanding and promoting learning theories," International Forum of Teaching & Studies, vol. 8, no. 2, pp. 5–11, 2012.

[56] P. Zaharias and A. Poylymenakou, "Developing a usability evaluation method for e-learning applications: Beyond functional usability," International Journal of Humun-Computer Interaction, vol. 25, no. 1, pp. 75–98, Jan. 2009.

[57] P. Zaharias and P. Koutsabasis, "Heuristic evaluation of e-learning courses: a comparative analysis of two e-learning heuristic sets," Campus-Wide Information System, vol. 29, no. 1, pp. 45–60, 2011.

AUTHOR BIOGRAPHIES

Taurayi Rupere is a researcher and lecturer in computer science. He has interests in studies involving multimedia e-learning design, implementation and usage, a branch in Human Computer Interaction (HCI). This research is part of his Ph.D. studies in multimedia e-learning practices. Taurayi's other research interest includes the use of IT in instruments in cloud and grid architectures. This research is one of the many types of research for usability in e-learning environments.

Dr. Maria Jakovljevic is an associate professor in computer science and has vast experience in Human and Computer Interaction and e-learning. She has supervised many students at Ph.D. and masters level. Her other research interests are in software applications and design which she has been coordinating a research team on software-industrial applications. She has also implemented and designed solutions for organization IT alignment to technological changes.