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Theorising and Modeling Interface Design Quality and its Predictive Influence on Learners' Post Adoption Behaviour in E-Learning Course Environments

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ABSTRACT

The current study, guided by the cross-sectional survey method, assessed interface design quality, and its predictive ability on E-learners' post-adoption behavior in E-learning course environments. DeLone and McLean's Information Systems Success Model, Khan's E-learning Framework, and Bhattacherjee's Information System Continuance Model formed the current study's theoretical underpinning. Data for the study were collected from 232 E-learners in selected Ugandan higher learning institutions, using a 38-item self-administered questionnaire. Principal Components Analysis produced a four-factor structure of interface design quality that comprised of content interactivity, accessibility design, system navigation, and visual-aesthetics design, which were found to be valid and reliable using Confirmatory Factor Analysis. The Structural Equation Model fit indices revealed that the hypothesised model achieved adequate goodness-of-fit to the data. Regarding the structural relationships, the four factors were found to be statistically significant predictors of E-learners' satisfaction; and in-turn, satisfaction impacted learning agility. The results have clearly aligned with the study's theoretical framework, buttressing existing empirical data on interface designs and end-user post adoption with E-learning interventions. The current study is crucial for making evidence-based pedagogical and design decisions by key E-learning stakeholders for the successful implementation and continued use of digital learning solutions in higher education contexts.

Keywords*: User interface design; structural equation modeling; satisfaction; E-learning course environments; accessibility; visual-aesthetics; learning agility; Uganda*

INTRODUCTION

As contemporary organizations, both educational and corporate continue to consider E-learning as an alternative approach to training and distance learning, there is need to understand the E-learning system characteristics that foster successful learning. To that end, the user interface feature has been pointed out as key (Center for Disease Control and Prevention, 2013; Kishabale & Sharifah, 2018; Kishabale, 2019). In the context of information systems, of which E-learning is part, interface design represents the general screen-presentation mechanism of a system that enables users to access, manipulate and perceive information (Kamaruddin, 2012). Meanwhile, the Center for Disease Control and Prevention (2013) has referred to the interface as the layout and appearance of the E-learning course environment that acts as a medium of communication to determine the extent of learner engagement. As clarified by Borchers (2001) cited in Kamaruddin (2012), interface design is not just about the visual-aesthetics design elements of fonts, images, color and general layout; but should be perceived as a communication medium that plays a mediation role between users and an information system. Given its instructional value, an E-learning user interface should reflect the usability attributes of learnability, memorability, error frequency, and subjective satisfaction (Davids, Chikte, & Halperin, 2014; Hollender, Hofmann, Deneke, & Schmitz, 2010). Weiss (1993) as cited in Kamaruddin (2012) has categorized the interface into four key domains - *presentation interface*: which affects how the user perceives information and is enabled by the elements of screen design like menus, visual elements, layout and color schemes; *communication interface:* which guides the process of communication between the user and the information system; *navigation interface:* which orients the user between frames/screens on information; and *explanation interface:* which helps in controlling how the information system supports the users' needs and activities via explanatory tools like textual and visual cues. Lee and Owens (2004) have offered several guidelines regarding the design of interfaces for multimedia, including: keeping it simple, while maintaining adequate white spaces and consistent spacing; keeping consistency of screen areas that have repeated controls like titles, menus, hyperlinks and prompt options; keeping in mind a consistent navigation design for users' comfort.

Good interface design for E-learning serves several instructional purposes. For example, Pralle (2007) has observed that well-designed E-learning course environments help to minimize learner confusion and frustration, and instead offer a visually appealing and engaging platform for successful learning. On the contrary, Meyer, Gaskill & Vu (2015) warn that if user interfaces are not well designed, they will distract the students, increase stress and inhibit the quality of outcomes in the E-learning process. Faghih, Reza & Katebi (2013) and Cheon (2008) in a related study have added that a program that is not user-friendly, with uncluttered interfaces, will make users concentrate more on mastering its navigational structure rather than focusing on instructional content, regardless of its computational functionality. Despite the enormous role played by well-designed user interfaces in E-learning, limited attention and detail has been paid to what constitutes user interface design, and its relationship with E-learning satisfaction and willingness to continue using E-learning in the context of Ugandan higher education. To plug this theoretical gap, the current study sought to assess and deconstruct the nature of E-learning user interface quality and its predictive ability on learner satisfaction and learning agility. In a bid to achieve the current study's purpose therefore, four specific objectives were framed as follows:

1. Explore the underlying factor structure of interface design quality as reported by the E-learners
2. Establish the extent to which the user interface design quality sub-constructs are psychometrically sound
3. Validate the goodness of fit of the hypothesised Elearning interface design quality model
4. Find out the predictive ability of content interactivity, accessibility design, system navigation, and visual-aesthetics design on learner satisfaction with E-learning course environments
5. Establish the extent to which learner satisfaction significantly predicts learning agility with E-learning course environments

THEORETICAL UNDERPINNINGS AND HYPOTHESIS DEVELOPMENT

Khan's E-learning Framework (2005)

The E-learning framework propounded by Badrul H. Khan (2005) is one of the comprehensive theoretical frameworks applied in the assessment of E-learning programmes. As illustrated in Figure 1 below, Khan's E-learning Framework is an octagonal framework that represents dimensions of interface design, pedagogy, technology, management, resource support, evaluation, ethics and institutional issues.

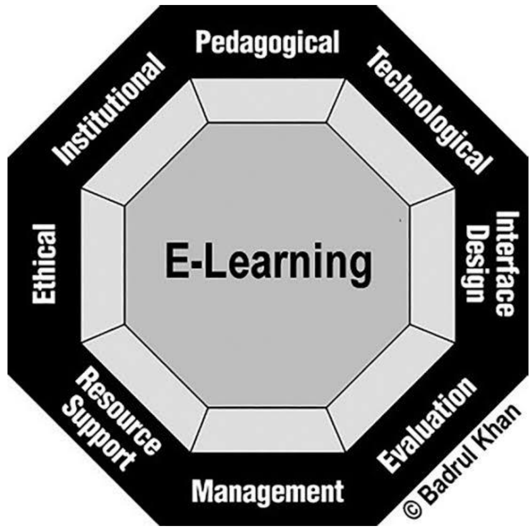

***Figure 1**:* Khan's (2005) E-learning Framework

At a broader level, the eight dimensions of Khan's E-learning framework can be grouped into the organizational, technological and educational domains. In the current study however, focus was on the interface design dimension to help shed light on the user interface design characteristics. The interface design dimension details the general look and feel of the E-learning environment in terms of content, site, and navigation design aspects (Khan, 2005).

DeLone and McLean Information Systems Success Model (2003)

The Information Systems Success Model theorizes that the success of any information system is a function of different but interrelated variables. As illustrated in Figure 2 below, the DeLone and McLean (2003) model comprises the six dimensions of: (i) system quality, (ii) information quality, (iii) service quality, (iv) use/intention to use, (v) net benefits, and (vi) user satisfaction (DeLone & McLean, 2003; Wang et al., 2007). In essence, the attributes of information, system and service quality are hypothesised to impact on both user satisfaction and intention to use/use as outcome variables. In turn, the two outcome variables impact on net benefits. However, net benefits are postulated to have a backward influence on both satisfaction and intention to use/use.

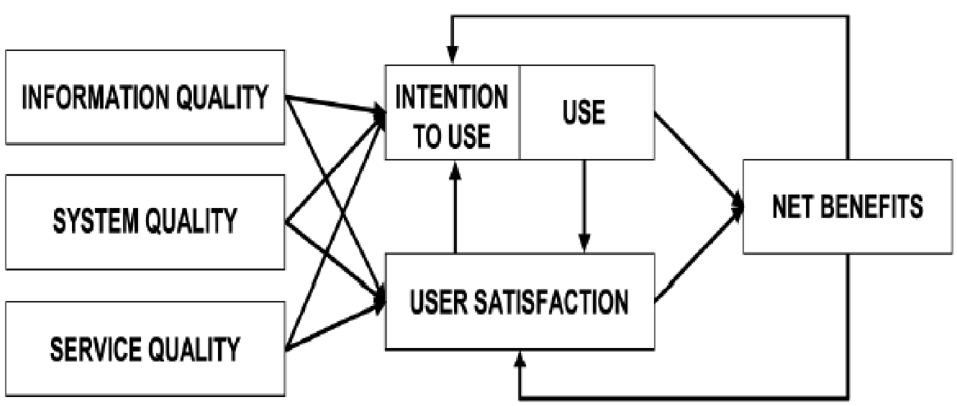

***Figure 2**:* DeLone and McLean's Information Systems Success Model (2003)

For purposes of the current study, the theoretical constructs, system quality and user satisfaction have been adapted.

Bhattacherjee's Information System Continuance Model (2001)

The Post-acceptance model, otherwise commonly referred to as the Information Systems Continuance Model (Bhattacherjee, 2001), is an extension of Oliver (1980) Expectancy Confirmation Theory. Unlike the TAM Model, the Information Systems Continuance Model focuses on user long-turn willingness to continue using information technology after the initial adoption decision (Bhattacherjee, 2008). At the heart of the model is the postulation that the success of an information system/technology is dependent on its continued use rather than just first-time adoption (Bhattacherjee, 2001b). Thus, as shown in Figure 3 below, the constructs of perceived usefulness and confirmation affect user satisfaction with an information system, although, perceived usefulness has been theorised to directly affect continuance use intention. Furthermore, user satisfaction impacts on information systems continued use.

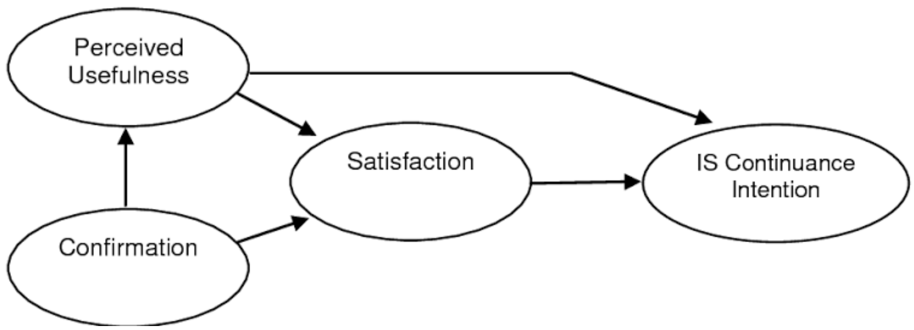

***Figure 3**:* Bhattacherjee's Information System Continuance Model (2001)

In the current study, the constructs of satisfaction and Information System Continuance Intention have been adopted to better under learners' post-adoption behavior satisfaction and learning agility with E-learning environments. With the help of the three theoretical models/frameworks - Khan's (2005) E-learning Framework, DeLone and McLean's (2003) Information Systems Success Model, and Bhattacherjee's (2001) Information System Continuance Model, an E-learning User Interface Design Quality model has been hypothesised in Figure 4 below.

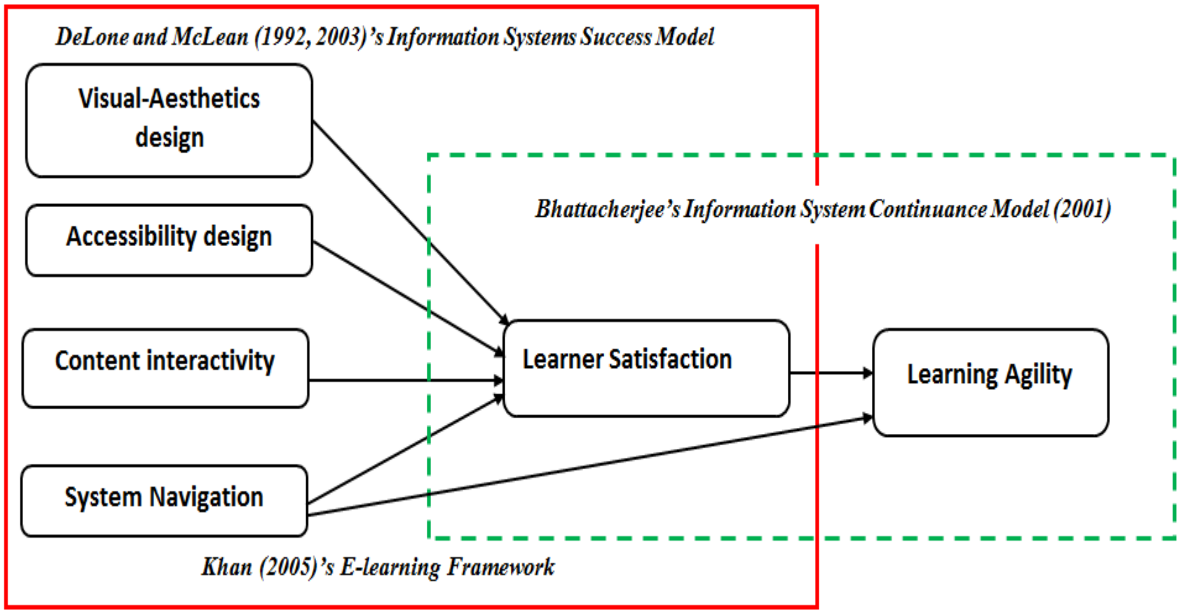

***Figure 4**:* Hypothesised E-learning Interface Design Quality Model

Thus, guided by the literature on user interface design and the theoretical framework, the following are three of the hypotheses for the study:

> **H$_{a1}$:** *Interface design quality is a multi-dimensional construct consisting of distinct but inter-related dimensions*
>
> **H$_{a2}$:** *The measure of the multi-dimensional interface design quality is construct-valid*
>
> **H$_{a3}$:** *The hypothesised E-learning Interface Design Quality model fits the data*

Content interactivity and Learner Satisfaction with E-learning

Interactivity is a pedagogical requirement in any E-learning course, as it provides learners with opportunities for content exploration, self-assessment through various quizzes, and other instructional activities that require E-learners to use navigational controls (Center for Disease Control and Prevention, 2013). Content interactivity refers to the intensity and quality of time the E-learner expends with course content, while reading, viewing tests, listening/watching audio-visual material, reading power point slides, web pages, participating in discussion forums and completing quizzes (Su *et al.*, 2005). Elements of interactivity may include but are not limited to hyperlinks, navigation controls, simulations, graphics, animations, audio and video objects, in-built exercises and assignments. The nature and degree of interactivity that occurs between the E-learner and instructional content is critical (Kishabale, 2019), as it has been found to impact on student learning outcomes and rates of course completion (Zimmerman, 2012; Murray *et al.*, 2013). Content interactivity has been closely linked to learner satisfaction in E-learning. A case in point, Zimmerman (2012) found that there existed a statistically significant and positive influence on the amount of time dedicated by students while interacting with instructional materials and academic achievement. Fatma and Mustafa (2016) also revealed the existence of a statistically significant influence of student-content interaction on the level of achievement in online learning. Meanwhile, Byers (2010) reported that content-interaction techniques like simulations, interactive references, hands-on activities, and personalized feedback significantly contributed to student satisfaction in E-learning. The above findings clearly support the propositions of Murray et al. (2013) that as learners spend more time viewing E-content, their levels of achievement in the course and overall course performance will improve. In light of the foregoing review of literature, one of the hypotheses for the current study is as follows:

> **$H_{a4:}$** *Content interactivity exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments*

Accessibility Design and Learner Satisfaction with E-learning

In the current digital age, it is undeniable that E-learning environments are essential in supporting conventional and life-long learning. However, the benefits of E-learning could be diminished if users cannot access the digital resources because of their disabilities. Accessibility has been defined as the extent to which the learning environment adjusts to the needs of all users regardless of their limitations which may arise from the environment, the tools used or conventional disability (IMS Global Learning Consortium, 2002; Shollar, Hana & Elgaber, 2010; Cooper et al., 2007) as cited in Boateng, 2016). The implication therefore is that E-content designers should provide instructional content in multiple forms - text, video, audio, in an attempt to surpass the various limitations learners may have. According to the World Wide Web Consortium (2012), the following accessibility guidelines should be applied in the process of designing accessible content: *robustness* (the content should be dynamic to adjust with changes in technology); *perceivability* (the user interface and content should be presented in a manner that is easy to understand); *operability* (the user should find it easy to work with the interface); *understandability* (the user should be able to understand and manipulate the user interface). In addition, Shollar et al. (2010) has suggested that accessibility is reflected in the four dimensions of *findability* (learners can easily and quickly locate learning content in the E-course), *shortcuts availability* (keyboard shortcuts have been availed for accessing commonly used commands), *browsers independence* (compatibility of several browsers), and *textual content option for multimedia content* (provision of non-text components of the content). In a study on system quality and E-learning, Majed (2013) found that about 75% of the respondents attached importance to accessible learning content. In addition, Buzzi, Buzzi, Leporini, & Mori (2012) have emphasised the need for accessibility and usability in the design of interfaces. In a study on accessibility for E-learning, Boateng (2016), learners reported the ability to access content, interact with content and learning from the E-learning environment as being important to them. Guided by the above discussion, this study hypothesizes that:

> **$H_{a5:}$** *Accessibility design exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments*

System Navigation and Learner Satisfaction with E-learning

Navigation is an attribute of user interface design that focuses on visible navigational and orientation support like the menu structure and links that empower learners' control over the instructional content (Alsheri, Rutter and Smith, 2019). Navigation is important in minimizing learner disorientation which may take the form of: the learner not knowing what to do; the learner not understanding the nature of the information system; or getting lost in the network of navigation links (Khentout *et al.*, 2006). As suggested by Anderson (2006) and Tollet et al. (2002) cited in Cheon, (2008b), navigation serves four main purposes: enables the learners to easily move from one part of the information system to another; provides an appealing look and feel of the learning site; creates a unique identifier of the learning site; and communicates with clarity the essential components of the site. System navigation can be well conceptualized using several sub-dimensions including, navigational support: the degree to which navigational options are evident on each frame to enhance memorability; reliable links: how correct and reliable the hyperlinks are;

clarity of sequence: the extent of clarity and sequence of pages so that users do not get lost; Quit and return with ease: the capability of users to leave as desired and return to the closest last visited point in the E-learning system with ease. According to Lee and Owens (2004), system navigation options for user interfaces should include: a frame identifier; navigational buttons of exit, next, back; bookmarking; a glossary button; help button; audio/video player controls; and lesson and topic buttons.

A few available empirical studies have tried to link information system navigation to user satisfaction. For example, Islam (2011) reported that perceived system quality in terms of navigation, functionality and interaction significantly impacted end-users' satisfaction with the E-learning system. In addition, in an experiment on comparing the nature of browser interfaces on web information management, Li and Chen (2010) found that topic browser interface type significantly reduced learner orientation, fostered learning retention and task accomplishment unlike the traditional tabbed browser interface. Reis et al. (2012) in a study on reducing cognitive load and enhancing usability, reported that user interfaces that do not reveal extraneous user options enabled novice learners to excel in their learning tasks. From all these empirical studies, it can be adduced that to provide memorable E-learning experiences to learners, user interfaces should be designed with the required navigational tools that minimize disorientation and increase user confidence in the learning environment. Thus, this study hypothesizes that:

> $\mathbf{H_{a6}}$: *System Navigation exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments*
>
> $\mathbf{H_{a7}}$: *System Navigation exerts a statistically significant direct influence on learning agility with E-learning course environments*
>
> $\mathbf{H_{a8}}$: *Learner satisfaction mediates between system navigation and learning agility with E-learning course environments*

Visual-Aesthetics Design and Learner Satisfaction with E-learning

The application of aesthetic standards to E-learning course content development enhances both the visual outlook instructional content and the learners' reaction to the overall course (David and Glore, 2010). Aesthetics, a branch of philosophy pertains to art and beauty, as well as how we perceive and judge objects on the basis of the information we receive through other sensory inputs (Mbipom and Harper, 2009; Zhang, 2009; Maity, Madrosiya and Bhattacharya, 2016) . Thus, aesthetics has a lot to do with feeling, affect, mood, and emotions that connect the users to a product/object (David and Glore, 2010). In the context of user interfaces, aesthetics design is critical as it has been found to shape the users' perceptions regarding the usability of a given system (Mbipom and Harper, 2009; David and Glore, 2010). The aesthetic aspects of an E-learning interface design comprises of sub-dimensions like: *layout structure*: the extent to which the interface adheres to a suitable layout hierarchy; *overall consistency*: the capability of the E-learning interface to function with consistency across the entire course; *terminology, font and color consistency*: the extent to which terminology, icons and symbols are applied with consistency in the course; *informative layout*: the degree to which the critical information on the user screen is positioned in areas that will easily catch attention; and, *readability:* how the used fonts, texts and color schemes are easy to read (Alsheri, Rutter and Smith, 2019). The above classification of visual aesthetics seem to align closely with Moshagen and Thielsch (2010) who have grouped the facets of aesthetics design in terms of: (i) Simplicity (pertaining to the aspects that enhance how we perceive an interface layout in terms of item grouping, order, clarity and homogeneity), (ii) Diversity (extent of visual richness, novelty, dynamism, creativity and variety), (iii) Colourfulness (color patterns and their corresponding constituent parts), and Craftsmanship (extent of skill applied to site design).

In addition, Shollar et al. (2010) have highlighted four dimensions of visual design as follows: *Legibility*: the ease with which text can be read on the display; *consistency*: the degree to which the layout of the interface and its primary elements are in harmony with the overall learning environment; *attractiveness*: how pleasing and enjoyable the interface is to the eye so as to get the user engaged; *simplicity*: how clear and uncluttered the interface is. The aesthetics design of an E-learning course environment, specifically the elements of layout, graphics, and color scheme contribute significantly to learner engagement and persistence (David & Glore, 2010). Aesthetic design has been found to correlate with how end users perceive, attach credibility and usability to particular information. For example, Maity, Madrosiya and Bhattacharya (2016) have highlighted that aesthetics has an impact on usability perceptions and the users' overall experiences with online services, and is therefore very relevant in the design of E-learning systems; while Sánchez-franco *et al.* (2013) have reported visual design as one of the key predictors of users' positive impressions of, preference for, and emotional attachments and affective experiences with digital learning environments. It therefore becomes important that developers of E-learning courses and learning platforms attach as much value to the concepts of visual-aesthetics design. In light of the reviewed literature, the current study hypothesizes that:

> $\mathbf{H_{a9:}}$ *Visual-aesthetics design exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments*

Learner Satisfaction and Learning Agility with E-learning Courses

Satisfaction is one of the key variables that significantly accounts for the E-learners' overall experience with the learning environment (Bowyer and Chambers, 2017). The concept of satisfaction in the context of learning has been defined as the perception of enjoyment, accomplishment, and contentment that a learner feels in an instructional environment, which represents an amalgamation of experiences with the learning content and the accompanying instructional activities (Chen, 2014; Dayal, Sandhu, & Archana, 2014; Lo, 2010; Strachota, 2006). The successful use of E-learning tools and environments has a significant relationship with the level of learner satisfaction and level of learning agility (Chen, Lee and Hsiao, 2018), which is an indicator that the E-learning environment has been well designed (Kuo, 2010; Lin, Chen, & Fang, 2011). Learning agility has been defined by Kim, Hong, and Song (2018), Meuse, Dai, and Hallenbeck (2010), and Lombardo and Eichinger (2000) as the ability of individuals to continue learning and their level of willingness to apply the newly acquired knowledge to new contexts. As characterized by Kim et al. (2018) and Meuse, Dai and Hallenbeck (2010), agile learners analyse problems with precision and accuracy, easily synthesize and comprehend complex information, show curiosity at new learning situations, and is flexible at problem solving. Satisfaction with E-learning has been found to impact the extent to which the E-learner engages, persists, and decides to continue using the course environment (Costley *et al.*, 2017; Kintu, Zhu and Kagambe, 2017). Note that, when learners are not satisfied with an E-learning environment, they will be demotivated to participate in online activities, which eventually results in dropout from the course (Featro, 2012). Thus, based on the foregoing discussion, the current study hypothesizes that:

> $\mathbf{H_{a10:}}$ *Learner satisfaction exerts a significant predictive ability on learning agility with E-learning course environments*

METHODOLOGY

Sample Profile

The study sample was made up of 232 learners who were drawn from three purposively selected CISCO Networking Academies in Uganda that were running E-learning courses. Of the 232 E-learners, the male gender was the most dominant (over 65%), while the females trailed with about

35%. Meanwhile, the respondents were taking the E-learning courses of CCNA (85%), CCNP (just over 7%), while IT Essentials and Cyber Security trailed with 4.3% and 3.4% respectively. The descriptive statistics further revealed that 51% of the E-learners rated themselves as having intermediate ICT knowledge, followed by those who self-rated as beginners at about 34%. 16% of the respondents rated themselves as being at advanced level in terms of ICT knowledge.

Instrumentation

To collect the quantitative data, a self-administered questionnaire with 39 items measuring interface design quality and learners' post adoption behavior with E-learning courses was used. The measurement items for the self-administered questionnaire were largely adapted by extensively reviewing available literature on the constructs of interface design attributes, learner satisfaction, continued learning intentions, and learning agility, especially from the works of Kim, Hong, and Song (2018); Moshagen and Thielsch (2010); Bhattacherjee, Perols, and Sanford, (2008); Georgiadou, Economides, Michailidou, and Mosha (2001); Kishabale and Sharifah (2018); Kishabale (2019); Norzaini and Redzuan (2016); and Wang, Wang, and Shee (2007) . The items were ordered in the questionnaire in such a way that they represented six theoretical sub-constructs, namely Visual-Aesthetics Design (8 items), Accessibility Design (5 items), System Navigation (8 items), Content Interactivity (6 items), Learner Satisfaction (7 items with α=.879) and Learning Agility (4 items with α=.823). The E-learners self-rated their perceptions regarding the interface design attributes and learning agility on 5 response categories of "Strongly disagree", "Disagree", "Neutral", "Agree", and "Strongly agree". Satisfaction was rated based on "Very Dissatisfied", "Dissatisfied", "Neutral", "Satisfied", and "Very satisfied". The reliability indices via Cronbach Alpha for the interface design quality measures are shown in Table 1.

Data Analysis Procedures

The data analysis process involved three key stages of multivariate analysis in a bid to achieve the objectives of the current study. First, dimensional analysis was conducted with the help of Principal Component Analysis (PCA) based on the Promax rotation method, to explore the multidimensionality of the interface design quality construct. Next, Confirmatory Factor Analysis (CFA) was run using AMOS (Version 22.0) to validate the measurement model. Lastly, full-fledged Structural Equation Modeling (SEM) was carried out to verify the adequacy of the structural model, as well as the structural relationships among the predictor and outcome variables in the study.

RESULTS

Underlying Factor Structure of Interface Design Quality

***Table 1**: Underlying Factor Structure of Interface Design Quality and Item Statistics*

Code	Dimensions/items	Mean	SD	Factor Loading*
Content Interactivity (Alpha=0.749)				
ci1	▪ Uses a variety of drag and drop activities in the learning content	3.25	1.39	0.730
ci2	▪ Allows me to access extra learning content outside the course	3.75	1.32	0.749
ci3	▪ Allows me to easily save learning content in a familiar format	3.68	1.36	0.734
ci4	▪ Gives me hints on how to complete learning activities like quizzes	3.76	1.36	0.520

ci5	▪ Uses drag and drop objects	3.54	1.38	0.525
ci6	▪ Uses videos content	3.42	1.45	0.605
	Visual-Aesthetics Design (Alpha=0.908)			
vad1	▪ Layout that is easy to understand	3.82	1.24	0.637
vad2	▪ Layout that appears well structured	3.94	1.09	0.737
vad3	▪ Site that appears consistent	3.88	1.04	0.852
vad4	▪ Design elements go together	3.85	1.12	0.739
vad5	▪ Features are attractive to me	3.86	1.09	0.815
vad6	▪ Layout shows a sense of creativity in design	3.88	1.08	0.729
vad7	▪ Color composition is attractive to me	3.87	1.14	0.858
vad8	▪ Layout appears professionally designed	3.94	1.08	0.560
	Accessibility Design (Alpha=0.8)			
acd1	▪ Can be navigated with the keyboard in the absence of a mouse	3.77	1.22	0.632
acd2	▪ Is compatible with screen sizes of handheld gadgets	3.79	1.21	0.558
acd3	▪ Provides font size, type, and spacing that are easy to read	3.95	1.11	0.702
acd4	▪ Provides me with page options that are consistent	3.85	1.13	0.707
acd5	▪ Presents course content in multiple formats	3.97	1.10	0.637
	System Navigation (Alpha=0.896)			
nav1	▪ Has navigational tools on all pages	3.53	1.25	0.55
nav2	▪ Enables me to control my learning progress.	3.85	1.12	.607
nav3	▪ Has well organized pages	4.06	1.03	.691
nav4	▪ Has predictable screen changes	3.64	1.30	.682
nav5	▪ Presents me with a logical sequence on how to complete tasks	3.66	1.22	.738
nav6	▪ Gives me clear page directions.	3.83	1.17	.643
nav7	▪ Allows a new page to open in a new browser window	3.81	1.20	.871
nav8	▪ Requires less scrolling no matter the screen size used	3.81	1.10	.658

* Extracted from Principal Component Analysis via Promax rotation

The descriptive statistics (mean and standard deviation) for the items involved in dimensionality reduction are shown in Table 1. The mean score for all items were well above the hypothetical mean of 2.5, as all of them were at least 3.2 and above. The implication here is that the E-learners reported having a much better understanding regarding their perceptions on interface design quality. In addition, the internal consistency indices of the responses to the respective items were adequately high and satisfactory, all above 0.7, with the minimum being 0.749 (Pallant, 2007)**.** To establish the underlying factor structure of the 27 items that measured interface design quality, Principal Component Analysis (PCA) was conducted.

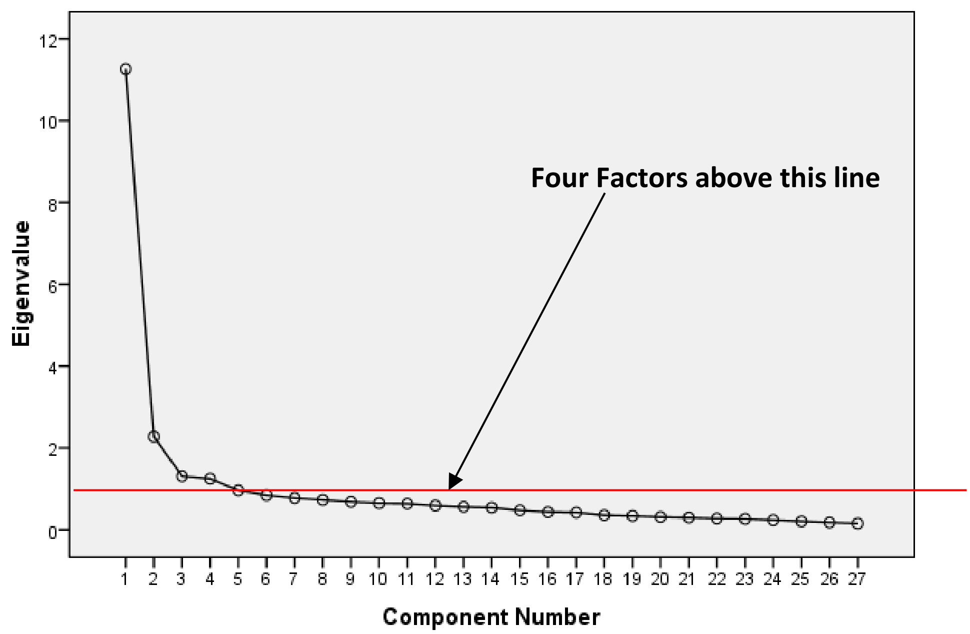

Figure 5*:* Scree plot

The initial results showed that the dataset was suitable for PCA as seen with χ2 (351) = 3596.637, p = .000, and KMO measure of sampling adequacy = .928. As earlier postulated, PCA extracted four underlying factors with eigenvalues greater than 1 (Factor 1=11.263, Factor 2=2.275, Factor 3=1.308, and Factor 4=1.246), with each of the factor loadings being statistically significant. The scree plot in Figure 5 above gives more evidence of the four factors derived after the Promax rotation. As shown in Table 1, the four factors were named accordingly as Visual-Aesthetics Design, Accessibility Design, System Navigation, and Content Interactivity. The PCA results have helped to achieve objective 1 of the study which sought to explore the underlying factor structure of interface design quality.

Validating the Multidimensionality of Interface Design Quality Construct

To test the validity of E-learners' subjective measure of interface design quality, a confirmatory factor analysis (CFA) procedure was conducted.

The results of the measurement model are shown in Figure 6 below and indicates that the four-factor structure was adequate in representing the data at hand. The goodness-of-fit for the model was satisfactory given that (χ^2/df=1.969, CFI=.911, and RMSEA=.065).

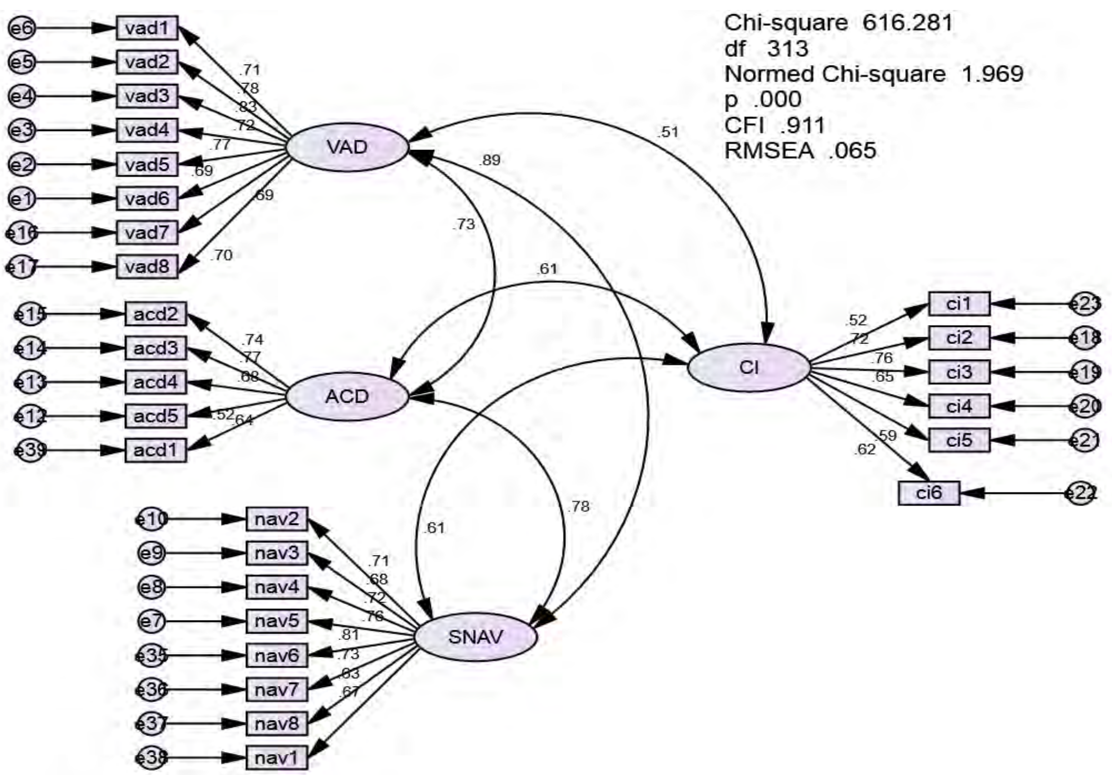

***Figure 6**:* CFA Results confirming a Four-Factor Model of E-learning User Interface Design

Further evidence pertaining to the validity of the measurement model is provided in Table 2 below in terms of composite reliability, convergent and discriminant validity. The data (as shown along the diagonal) indicate that the Average Variance Extracted (AVE) for each of the interface design sub-constructs exceeded the threshold for convergent validity of 0.5. Additionally, the measurement model demonstrated adequate discriminant validity given that AVEs were larger than most of the shared variances above the diagonal. The inter-factor correlations (below the diagonal) equally demonstrated that the interface design quality was indeed a multidimensional construct with distinct but inter-related sub-constructs. Moreover, the composite reliability scores for each of the dimensions were far above the threshold of 0.7 Visual-Aesthetics Design (.909), Accessibility Design (.784), System Navigation (.875), and Content Interactivity (.814).

In conclusion therefore, with the help of CFA, objective 2 of the study that sought to establish the extent to which the interface design quality sub-constructs are psychometrically sound in terms of reliability, convergent validity and discriminant validity has been achieved.

***Table 2**: Average Variance Extracted (AVE), Inter-factor correlations and shared variance among the sub-constructs*

Dimension	**VAD**	**ACD**	**SNAV**	**CI**
VAD	**0.847**	0.534	0.801	0.265
ACD	0.731	**0.647**	0.608	0.376
SNAV	0.895	0.78	**0.68**	0.377
CI	0.515	0.613	0.614	**0.625**
Composite Reliability	0.909	0.784	0.875	0.814

NB: AVEs shown diagonally; Correlation matrix below the diagonal; share variance above the diagonal

Adequacy of the Hypothesised E-learning User Interface Structural Model

The Structural Equation Modeling results that were intended to address the third objective of the study are summarized in Table 3 below. On the recommendations given by Hair, Black, Babin, & Anderson (2016), Byrne (2010), Awang (2015), and Matsunaga (2011), the adequacy and validity of the hypothesised user interface design quality model was examined using absolute, incremental, and parsimonious indices.

***Table 3**: Summary of Fit Indices for the structural equation mode*l

Model fit category	**Fit index**	**Level of acceptance**
Absolute fit	Chi-square (χ^2)	The smaller the better
	Root Mean Square of Error Approximation (RMSEA)	<.05 to <.08
	Goodness of Fit Index (GFI)	>.90
Parsimonious fit	Chi-square/Degrees of Freedom (χ^2/df)	<3 to <5
Incremental fit	Comparative Fit Index (CFI), Tucker-Lewis Fit Index (TLI)	>.90

The results of the Structural Equation Modeling are shown in Figure 7 below. The data reveals that the model fit indices were well above the threshold as required (χ^2/df=1.733, CFI=.904, and RMSEA=.056), which was a clear indicator of the fit relationship between interface design quality and post adoption behavior (Matsunaga, 2011; Awang, 2015). In addition, results of the multivariate analysis showed that collectively, the four predictor variables of visual-aesthetics design, accessibility design, system navigation, and content interactivity were able to explain 67% of E-learners' variability in satisfaction; and finally, satisfaction accounted for up to 61% of learning agility with E-learning courses.

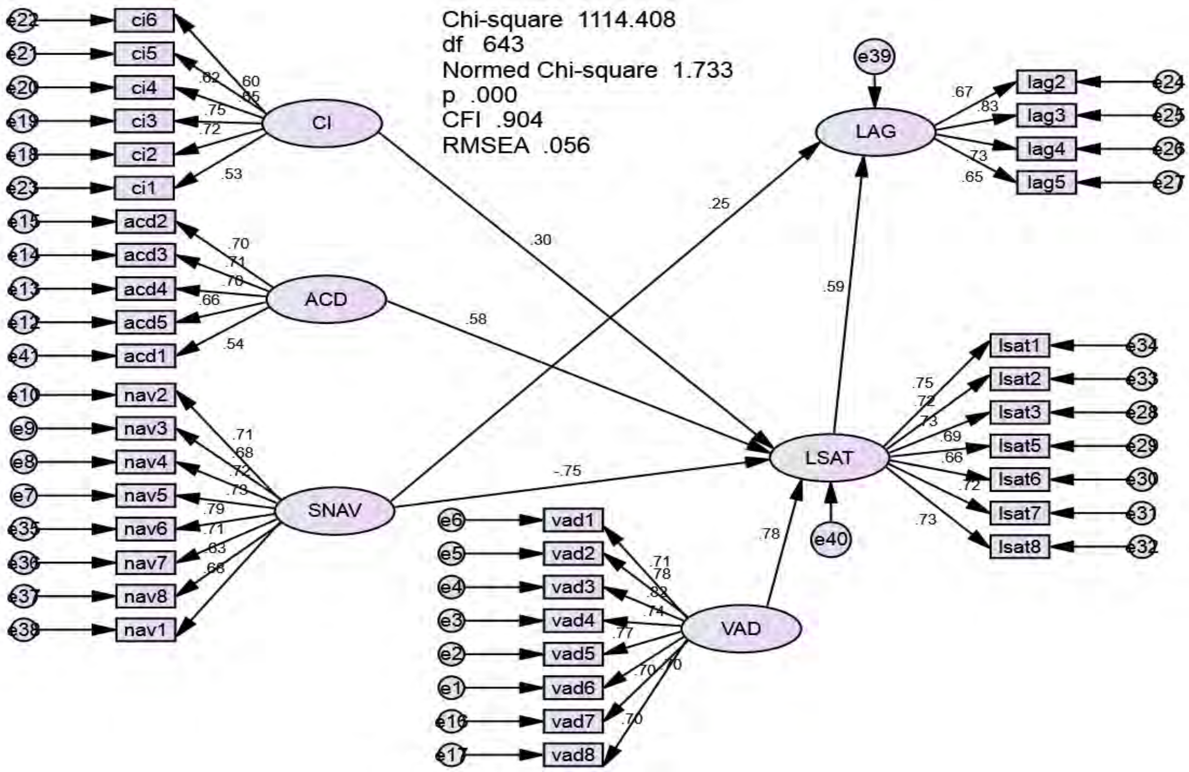

***Figure 7**:* E-learning User Interface Structural model

Note: VAD (Visual-Aesthetics Design), ACD (Accessibility Design), SNAV (System Navigation), CI (Content Interactivity), LSAT (Learner Satisfaction), LAG (Learning Agility).

Assessment of the Structural Relationships between E-learning Interface Design Quality and Learner Post-Adoption Behaviour

Research objective 4 sought to assess the predictive influence of the four interface design factors on learner satisfaction and therefore test hypotheses three to eight (Ha_3-Ha_9). Meanwhile, research objective 5 analyzed the influence of satisfaction on learning agility with E-learning courses. To that end, the structural model's standardized Beta estimates and p-values were examined. As seen in Table 4 below, all the path coefficients/estimates of the causal paths were positive and statistically significant at 0.05 level. The standardized path coefficients/estimates and the respective p-values were: VAD→LSAT (β=.782, p=.001); ACD→LSAT (β=.583, p<.001), NAV→LSAT (β=.751, p=.018), CI→LSAT (β=.302, p=.003), LSAT→LAG (β=.592, p=.001), and NAV→LAG (β=.253, p=.002).

Regarding hypothesis seven, learner satisfaction was found to exercise partial mediation between system navigation and continuance learning intention given that both the direct and indirect structural paths exhibited statistical significance.

***Table 4**: Standardised Beta Weights (β), CR, p-value for structural paths*

Structural paths	Estimate	S.E.	C.R.	*P-value*	Outcome
LSAT←CI	.302	.080	2.966	.003	Significant
LSAT←ACD	.583	.151	3.401	***	Significant
LSAT←SNAV (a)	.751	.267	2.361	.018	Significant
LSAT←VAD	.782	.236	3.276	.001	Significant
LAG←LSAT (b)	.592	.086	6.029	***	Significant
LAG←SNAV (c)	.253	.061	3.073	.002	Significant
a*b	.442	**Partial mediation** since both the direct and indirect effects are significant			
a*b>c	Mediation occurs				

***(P-Value=0.001)

The results of PCA, CFA and SEM analyses are summarized in Table 5 below, as per the respective hypotheses of the study. In specific terms, the outcomes of the study indicate that:

1. the measure of multi-dimensional interface design quality is construct-valid
2. the Interface design quality structural model fits the data; and
3. there is a positive and statistically significant influence of the predictors on the outcome variables in the model.

***Table 5**: Summary of results as per hypotheses*

Hypothesis statement	Decision
H_{a1}: Interface design quality is a multi-dimensional construct consisting of distinct but inter-related dimensions	Supported
H_{a2}: The measure of multi-dimensional interface design quality is construct-valid	Supported
H_{a3}: The hypothesised Elearning interface design quality model fits the data	Supported
H_{a4}: Content interactivity exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments	Supported
H_{a5}: Accessibility design exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments	Supported
H_{a6}: System Navigation exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments	Supported
H_{a7}: System Navigation exerts a statistically significant direct influence on learning agility with E-learning course environments	Supported
H_{a8}: Learner satisfaction mediates between system navigation and learning agility with E-learning course environments	Supported
H_{a9}: Visual-Aesthetics design exerts a statistically significant predictive influence on learner satisfaction with E-learning course environments	Supported
H_{a10}: Learner satisfaction exerts a statistically significant predictive ability on learning agility with E-learning course environments	Supported

DISCUSSION

The first and second objectives of this paper sought to explore the underlying factor structure of interface design quality, and validate its psychometric soundness in terms of reliability, convergent validity, and discriminant validity of the measure. The evidence of the PCA and CFA confirmed the multi-dimensionality and validity of the four-factor structure, thereby illuminating our further understanding regarding the concept of interface design quality in three key ways. First, this study established empirical evidence that interface design quality is indeed a multi-dimensional construct, as earlier highlighted by Hollender *et al.* (2010), Davids, Chikte and Halperin (2014), and Matraf and Hussain (2017). Second, the 27-item measure in the survey instrument used to assess interface design quality has been established to be of practical application in evaluating users' understanding and perceptions in the domain. Third, it is evident from the results that the four hypothesized sub-constructs of content interactivity, accessibility design, system navigation, and visual aesthetics design are distinct but related as they align with the interface design quality construct. Above all, reliability and validity of the four sub-constructs was verified when the four-factor structure demonstrated adequate internal consistency ($\alpha > 0.7$ for all sub-constructs); and composite reliability that ranged between 0.784 (Accessibility design) to 0.909 (Visual-aesthetic design) in keeping with (Pallant, 2007; Matsunaga, 2011; Awang, 2015). The measurement model further demonstrated evidence of convergent and discriminant validity of the relationship between the observed measures and the respective latent constructs, as seen with the Average Variance Extracted scores that exceeded the threshold for each of the sub-constructs, accompanied by relatively moderate inter-factor correlation values. To that end, objective one of the current study has been successfully achieved.

In regard to objective three; validation of the structural model in terms of its fit to the data, the analysis of results from full-fledge SEM showed that the hypothesized structural model of user interface design quality adequately fit the data as the fit indices well exceeded the required scores such that: $\chi^2/df=1.733$, CFI=.904, and RMSEA=.056 (Awang, 2015; Hair, Black, Babin, & Anderson, 2016; and Matsunaga, 2011). There is no doubt therefore, that the validity of the current structural model has further strengthened the applicability of the theoretical constructs that were adopted from Khan's E-learning Framework (Khan, 2005), Information Systems Success Model (Delone and Mclean, 2003), and the Information System Continuance Model (Bhattacherjee, 2001; Bhattacherjee, Perols & Sanford, 2008).

Regarding the fourth and fifth objectives which focused on the predictive ability of interface design quality sub-constructs on learner satisfaction, and in-turn, learner satisfaction on learning agility, to better test the predictive ability of the predictors, the objectives were accompanied by seven alternative hypotheses that were assessed at 0.05 level of significance. The results from full-fledge structural equation modeling revealed that the four factors were significant predictors of learner satisfaction with the E-learning course environments, accounting for up to 67% variance in learner satisfaction. Additionally, learner satisfaction was able to account for 61% of variance in learning agility with E-learning environments. In that regard, the predictive effect of content interactivity on satisfaction with E-learning was analysed. Results of the structural equation model showed that $\beta=.302$, $p<.05$, implying a practical significance of just over 30% to the model. In line with the above result, a meta-analysis by Croxton (2014) revealed the fact that interactivity is a critical aspect when it comes to measuring how satisfied and persistent learners are in online instructional settings. Meanwhile, Fatma and Mustafa (2016) reported a statistically significant predictive ability of learner-to-content interactivity on academic achievement; while Zimmerman (2012) found a positive relationship between the time-on task and their achievement levels.

The structural relationship between accessibility design and learner satisfaction yielded $\beta=.583$, $p<.05$, and therefore a practical significance of over 58% to the model. Thus, learners' ability to navigate the E-learning course based on multiple methods, course compatibility with screen sizes of handheld gadgets, user-friendly font attributes, and content presentation using multiple formats accounted for a great degree of satisfaction with E-learning course accessibility features. Along that line, Matraf & Hussain (2017) in their usability evaluation of mobile e-book applications found that accessibility significantly affected user satisfaction, explaining about 48% of the dependent variable; while navigation accounted for over 36% of variance in user satisfaction with the e-book application.

The predictive influence of system navigation on learner satisfaction was also assessed. The statistical analysis yielded $\beta=.751$, $p<.05$), with a practical significance of about 75% to the model. The direct predictive effect of system navigation on learning agility yielded $\beta=.253$, $p<.05$), with a practical significance of about 25% to the model. Further, hypothesis eight postulated that learner satisfaction mediates the causal relationship system navigation and learning agility. The SEM statistical analysis result revealed the existence of partial mediation, as both the direct and indirect effects were significant. The results in the current study supports that of Kishabale and Sharifah (2018) which reported a statistically significant influence of interface design quality on learner satisfaction; as well as a direct effect of interface design quality on learning agility with E-learning. Kishabale and Sharifah (2018) however did not go further to assess the mediation effect of satisfaction between interface design quality and learning agility, which the current study evaluated.

In testing hypothesis nine of the study, the predictive ability of visual-aesthetics design on learner satisfaction was $\beta=.782$, $p<.05$, with a practical significance of over 78%. This result closely aligns with Badran and Al-haddad (2018) study on the impact of the software user-experience and customer satisfaction which revealed that aesthetics of user experience accounted for about 40% of the variance in user satisfaction. In addition, a study on emotional design by Kumar, Muniandy, and Yahaya (2016) showed that learners who used the Multimedia Learning Environment with positive emotional design, exhibited higher levels of academic achievement unlike the users of other designs. Meanwhile, Sánchez-franco et al. (2013) in their assessment of perceptions of visual design found a significant effect of classical aesthetics on both perceived usefulness and user satisfaction. The current study results have further extended the investigation of Miller (2011) which revealed that aesthetics led to a significant reduction in learner cognitive load, enhanced learner satisfaction and continued use intentions with E-assessment. The current study finding has however contrasted with that of Kumar, Muniandy, and Yahaya (2018) on the effects of visual aesthetics in E-learning that reported statistically significant differences between the users of positive and negative aesthetic designs.

The current study theorized that satisfaction significantly predicted learning agility. Consequently, the regression coefficients of the structural path showed a significant influence ($\beta=.592$, $p<.05$), and hence a practical significance of almost 60%. Specifically, the E-learning course content usefulness, easy-to-use E-learning course functions, and the ability of the E-learning course to meet learner expectations contributed to such a high degree of continued learning intentions and agility. The results of this study are important to further strengthening the theoretical postulations of Bhattacherjee (2001b) and Bhattacherjee et al. (2008) that indeed satisfaction with information systems underpins its continued acceptance by respective users. In addition, the results have shown alignment with several existing empirical investigations. For example, Tawafak, Romli, & Arshah (2018) in their study on continued use of the E-learning platform, found that learner satisfaction positively affected continued use intention with the application. The study result has further aligned with Chiao-Chen (2013) who reported that library users' perceptions of value and levels of satisfaction were significant predictors of their continued use intentions with E-learning systems; and Li (2016)'s investigation that revealed the extent to which user satisfaction significantly influenced user continued use intentions to seek knowledge in virtual learning. Further, a significant variance in user intentions to continue utilizing an E-book (Tri-Agif, Noorhidawati and Ghalebandi, 2016), a virtual learning system (Antonio et al., 2015; Lin, 2012), MOOCs (Alraimi, Zo and Ciganek, 2015), smart gadgets as tools for ubiquitous learning (Aziz, 2015), and web-based learning system (Hung, Chang and Hwang, 2011) was greatly determined by their perceived satisfaction.

CONCLUSION AND RECOMMENDATIONS

The current study has made two critical contributions to the area of instructional technology in general and E-learning success, in particular. First, the study has contributed a valid and reliable 38-item questionnaire and an integrated model of user interface design quality, which will serve as an effective tool for assessing usability worthiness of E-learning instructional environments in line with learner post-adoption behavior. Specifically, the four user interface design dimensions of content interactivity, accessibility design, system navigation, and visual aesthetics design will help instructional designers and interface designers to take evidence-based decisions while creating user-friendly E-learning environments that foster positive learning outcomes. Second, the study has endeavored to extend relevance of the existing E-learning and Information systems models, by validating the applicability of the respective theoretical constructs to E-learning success. Moreover, the data generated from the study are essential in informing our on-going efforts in the process of planning, developing, and evaluating usable instructional interfaces critical to E-learning success. The significant results notwithstanding, the current study has three limitations. First, the study investigated the spectrum of usability facets that constitute user interface design quality, but as technologies keep evolving, periodic validation of the questionnaire will be necessary. Secondly, the respondents for the current study were a homogeneous sample of post-secondary learners taking CISCO E-learning courses in Uganda, and as such, the results may be different with learners of other E-learning courses and learning levels. Future investigations that make use of varied samples may bring unique insights for purposes of comparability of the measurement instrument across research contexts. Lastly, this study did not attempt to link interface design qualities with learner academic achievement with E-learning. This concern is worth investigating as the results of which may help instructional designers pay attention to usability aspects that improve E-learning performance.

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