Computers & Education 57 (2011) 2505–2516

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Design characteristics of virtual learning environments: state of research

Daniel Mueller*, Stefan Strohmeier [1]

Chair of Management Information Systems, Saarland University, Campus C3.1, 66123 Saarbruecken, Germany

ARTICLE INFO

Article history:
Received 6 January 2011
Received in revised form
28 June 2011
Accepted 30 June 2011

Keywords:
Design characteristics
Literature review
State of research
Virtual learning environments

ABSTRACT

Virtual learning environments constitute current information systems' category for electronically supported training and development in (higher) education(al) and vocational training settings. Frequently expected advantages of using virtual learning environments refer, for instance, to the efficiency, individuality, ubiquity, timeliness and learning task orientation. However, a crucial precondition of realising such advantages is an appropriate system design. Hence, the question "Which specific design characteristics actually characterise successful virtual learning environments?" is of specific interest for training and development practice. This paper therefore discusses virtual learning environments' design characteristics by conducting an in-depth literature review. Based on this, a comprehensive set of diverse design characteristics of virtual learning environments as well as particular information associated with them are elicited, presented and discussed. Beyond this, particular implications for research and practice are derived. This may contribute to a successful development, implementation and (continuous) improvement/evaluation of virtual learning environments.

1. Introduction

For decades electronic learning systems have been constituting the basic enablers of e-learning in the private and public sectors. Though designations as categorisations of such learning systems are rather heterogeneous and they also change over time, current systems can be pooled under the rubric of virtual learning environments (VLE). VLE can be understood as electronic information systems (IS) for the full administrative and didactical support of learning processes in (higher) education(al) and vocational training settings by providing learners with adequate learning resources to develop intended qualifications systematically (e.g. Fry, Ketteridge, & Marshall, 2009; Strohmeier, 2008; Weller, 2007). The development and application of VLE is justified on diverse advantages such as advanced collaboration and communication, convenience (costs, didactics, learning) efficiency, VLE user control, personalisation, ubiquity, task orientation and timeliness of VLE-driven learning and teaching (e.g. Ozkan & Koseler, 2009; Sitzmann, Kraiger, Stewart, & Wisher, 2006). Such advantages may also explain the ever-increasing adoption and impact of VLE on the design and development of both of them, (higher) education(al) and vocational training programs/curricula (e.g. Holsapple & Lee-Post 2006; Johnson, Gueutal, & Falbe, 2009; Wang, Wang, & Shee, 2007).

However, success strongly depends on the appropriate development, implementation and (continuous) improvement/evaluation of VLE, since only well-designed and hence appropriate VLE will yield success (Dennis, Wixom, & Roth, 2006; Kavanagh & Thite, 2009; Sommerville, 2007). Accepting that there also may be ill-designed VLE which are not successful directly leads to the question how successful VLE can be distinguished from unsuccessful ones. In this respect, "design characteristics" of VLE may offer a useful concept for both research and practice. Technically- (e.g. ISO, 2005) as well as managerially-oriented literature (e.g. DeLone & McLean, 1992, 2003; Venkatesh & Bala, 2008; Wixom & Todd, 2005) congruently understands design characteristics as a set of those inherent IS properties which determine IS success (e.g. Davis, 1993; DeLone & McLean, 2003; Van Aken, 2005; Venkatesh & Bala, 2008). It should be noted that design characteristic also apply to the category of VLE (e.g. Cho, Cheng, & Lai, 2009; Wang & Wang, 2009).

* Corresponding author. Tel.: +49 0 681 302 64752; fax: +49 0 681 302 64755.
E-mail addresses: d.mueller@mis.uni-saarland.de (D. Mueller), s.strohmeier@mis.uni-saarland.de (S. Strohmeier).
URL: http://www.mis.uni-saarland.de
[1] Tel.: +49 0 681 302 64751; fax: +49 0 681 302 64755.

0360-1315/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compedu.2011.06.017

Based on this background, the purpose of this paper is to provide an in-depth literature review on VLE design characteristics in order to elicit relevant characteristics as well as particular contextual information related to them systematically. This should contribute to future research and practice related to the development, implementation and improvement/evaluation of successful VLE.

For that design characteristics of VLE and their meaning for research and practice are briefly introduced (Section 2). Subsequently, the method of the literature review is introduced (Section 3), and the results obtained are presented and discussed (Section 4). Finally, major implications for research and practice are derived (Section 5), and some overall conclusions are illustrated (Section 6).

2. Design characteristics of VLE

A holistic approach of VLE is pursued to obtain generally valid knowledge on VLE design characteristics. In accordance with the literature, VLE are referred to the entire category of technology enhanced learning systems (Seddon, Staples, Patnayakuni, & Bowtell, 1999) offering full administrative- and didactical-supportive functionalities. In consequence, each sub-category of technology enhanced learning systems is included, e.g. adaptive learning environments (Tobing, Hamzah, Sura, & Amin, 2008), blended learning systems (Wu, Hsia, Liao, & Tennyson, 2008), digital libraries (e.g. Hong, Thong, Wong, & Tam, 2001–2002), distance education systems (e.g. Cho et al., 2009), e-learning services (Chiu, Hsu, Sun, Lin, & Sun, 2005), enterprise e-learning systems (Wang et al., 2007), online courses (e.g. Sun, Tsai, Finger, Chen, & Yeh, 2008) or learning-related search engines (e.g. Liaw, Chang, Hung, & Huang, 2006). Likewise, the VLE concept is not restricted to any application domain originating in the huge plethora of different (higher) education(al) and vocational training settings (e.g. companies, schools, [distance learning] universities). In brief, VLE are seen as comprehensive main category in the domain of technology enhanced learning.

Design characteristics are all those inherent properties of VLE which determine their success (e.g. Cho et al., 2009; Wang & Wang, 2009) – while VLE success is for instance conceptualised as users' behavioural intention to use, users' actual use of, users' satisfaction with, or users' (perceived) net benefits of deploying a VLE (e.g. Davis, 1989; Davis, Bagozzi, & Warshaw, 1989; DeLone & McLean, 2003; Seddon, 1997; Seddon, Graeser, & Wilcocks, 2002; Venkatesh & Bala, 2008). Since determining VLE success, adequate knowledge referring to design characteristics of VLE clearly is relevant to all VLE-related processes, i.e. the development, implementation and improvement/evaluation of VLE, and, hence, all VLE-related stakeholders, i.e. decision makers, system developers, system implementers, system evaluators and content providers (Dennis et al., 2006; Kavanagh & Thite, 2009; Mueller, Strohmeier, & Gasper, 2010; Sommerville, 2007). Given the general VLE approach described above, the current paper strives for generally valid VLE design characteristics which are not restricted to specific system (sub-)categories or specific application domains of VLE.

There are different possibilities to categorise VLE design characteristics. Following a common general theoretical categorisation of IS characteristics relevant to IS success, one can roughly distinguish system-, information- and service-related characteristics (DeLone & McLean, 2003). System characteristics are understood as a set of properties referring to the VLE systems functionalities (e.g. *reliable*). Information-related design characteristics are understood as a set of properties referring to learning materials inherent to VLE in particular (e.g. *relevant*). Finally, service-related characteristics do not directly relate to the VLE systems, but to the human-related support which complements the system (e.g. *responsive*). Since only system- and information-related characteristics therewith directly refer to VLE, they are used as the two major categories of VLE design characteristics in the following. Surrounding service-related aspects as well as further aspects such as instructor characteristics, user characteristics etc. are also relevant to learning success (e.g. Hornik, Johnson, & Wu, 2007; Piccoli, Ahmad, & Ives, 2001). However, they are evidently not related to the VLE design as such, and, hence, are not regarded as VLE design characteristics.

Given this, it is of particular academic interest to support practitioners in the specification, elicitation and evaluation of design characteristics in order to foster VLE success. To enhance VLE success even further, the compatibility between VLE design characteristics and VLE stakeholder requirements by means of user-centred design approaches should be ensured constantly (e.g. Bittner & Spence, 2003; ISO, 1999).

However, there is currently little research, and, hence, knowledge concerning VLE design characteristics (e.g. Cho et al., 2009; Fu, Chou, & Yu, 2007; Pituch & Lee, 2006; Sun et al., 2008). Eliciting and compiling a comprehensive and systematic set of system- and information-related VLE design characteristics, thus, is an important step in developing a better understanding of manageable design determinants of VLE success.

Hence, the major target group of this paper is researchers interested in a) previous findings related to this topic in general, and b) the creation of new conceptual, empirical and/or theoretical knowledge in particular. Subsequent to this, researchers may conduct further empirical investigations which may unfold or verify the real potential of the VLE design characteristics elicited (DeLone & McLean, 2003).

In order to achieve this goal, the subsequent elaboration of existing research on system- and information-related VLE design characteristics provides a deeper understanding of the methodological underpinning applied, presents and discusses the main findings, derives particular implications for research and practice, and illustrates some overall conclusions.

3. Method

A comprehensive literature review is conducted to obtain an overview of previous results concerning system- and information-related VLE design characteristics as well as particular contextual information related to them systematically. The review considers studies which directly deal with system- and information-related VLE design characteristics in a conceptual or empirical manner. Extensive search of electronic databases (EBSCO, Google [scholar], ScienceDirect and Scopus) as well as selected journals and conference websites is carried out to identify appropriate studies. However, only outlets with double blind peer review processes are taken into account in order to assure the quality of results. The search strings applied to elicit relevant literature combine design-related terms (e.g. design characteristics) with the context-related ones (e.g. e-learning, VLE). In total, more than 40 search strings are deployed (see Appendix). In an attempt to map existing studies comprehensively, a time frame of 20 years (1990–2010) is analysed. Revealed studies are subsequently reviewed manually by two independent raters. In case of high inter-rater reliability, studies are incorporated into the final analysis.

The studies are comprehensively analysed in terms of theoretical foundation, range of validity, definition, data gathering and data analysis method. These review criteria are briefly justified in the following: a theoretical foundation may support researchers in better

specifying relevant VLE design characteristics, success variables or particular relationships among them (Doty & Glick, 1994). In order to specify, elicit and evaluate VLE design characteristics properly it is important to know about the range of their validity. That is, are VLE design characteristics thought to be applicable universally (i.e. in the VLE context, and beyond)? Or are they thought to be limited to the deployment in the VLE context solely (Kuechler & Vaishnavi, 2008)? This, in turn, may further improve researchers' knowledge about VLE design characteristics, and thus facilitate a classification of the characteristics to be elicited into a "dichotomy of validity" (Mueller et al., 2010). Such a classification may again support researchers in better determining a set of contingent VLE design characteristics that best suit the requirements of particular VLE development, implementation and improvement/evaluation scenarios (DeLone & McLean, 2003). At the same time the specification and elicitation of universal vs. contingent design characteristics may enable researchers to compare and validate corresponding evaluation results with other system categories (e.g. data warehouse, e-commerce) or (specific sub-types of) VLE solely (DeLone & McLean, 2003). Beyond that, clear definitions may facilitate the textual comparability of system- and information-related VLE design characteristics with a standardised operationalisation. In addition to that, detailed knowledge about the evaluation of VLE design characteristics is an important step to clarify how far a VLE actually meets relevant VLE design characteristics, respectively, relevant VLE stakeholder requirements fostering VLE success. Consequently, methods of data gathering and analysis are investigated in more detail. Thereby, more in-depth knowledge about the data source of VLE design characteristics may support researchers in making evaluation results and, thus, implications for research and practice, more generalisable. This presumption is due to the fact that data gathering procedures conducted across different application domains (e.g. across different companies, schools, [distance learning] universities) are considered to yield more valid results than those data gathering efforts limited to a single application domain (e.g. based on one particular university). Finally, the VLE design characteristics revealed by use of this literature review are presented. Thereby, the VLE design characteristics are illustrated according to their level of granularity conceptualised as the "grade of detailedness and operativeness" of these characteristics, and their impact on various (dependent) VLE success variables (Mueller & Strohmeier, 2010, p. 211).

4. Results and discussion

4.1. Overview

By means of the method applied, 30 relevant studies[2] are identified. Studies and review results are summarised in Table 1. The analysis of the review criteria yields some interesting insights which are illustrated in more detail within the subsequent sections.

4.2. Theoretical foundation

Fortunately, the majority of studies show a theoretical foundation (see Table 1). In particular, there is a dominant focus on two prominent approaches: the technology acceptance model (TAM) (e.g. Davis, 1989; Davis et al., 1989), and the DeLone & McLean IS Success Model (ISSM) (e.g. DeLone & McLean, 1992, 2003; see Table 2).

The TAM posits that users' behavioural intention to use, respectively, their actual use of a VLE is determined by two beliefs. These are uses' perceived usefulness and perceived ease of use of a VLE. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Ajzen & Fishbein, 2005; Davis, 1989, p. 320). Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320).

Constituting a parsimonious theory, however, the TAM subsumes specific VLE design characteristics under an overall container in the shape of *systems characteristics*. *Systems characteristics* are theorised to have an effect directly on both perceived usefulness and perceived ease of use, which, in turn, are thought to mediate the effect of these *systems characteristics* on users' behavioural intention to use, respectively, their actual use of a VLE (Ajzen & Fishbein, 2005; Davis, 1989, 1993; Davis et al., 1989; Venkatesh & Bala, 2008; Venkatesh, Morris, Davis, & Davis, 2003).

As distinct from the TAM (Davis 1989; Davis et al., 1989), the ISSM represents a parsimonious framework for categorising design characteristics relevant to the success of IS in general (DeLone & McLean, 1992, 2003; see Table 2). The ISSM classifies *system* and *information quality* as essential groups of VLE design characteristics. Hence, these two categories guide the elicitation of design characteristics decisively. Furthermore, and as distinct from the initial ISSM (DeLone & McLean, 1992), the updated ISSM states that the impact of these design characteristics on the conflated success category "(perceived) net benefits" is fully mediated by users' behavioural intention to use, respectively, their actual use of, or satisfaction with a VLE (DeLone & McLean, 2003). However, the model itself is not able to provide more detailed information about VLE design characteristics.

However, object-based beliefs inherent to the updated ISSM (e.g. *system* and *information quality*) are proven to constitute mostly weak direct predictors of users' behavioural intention to use, respectively, their actual use of a VLE (Ajzen & Fishbein, 2005; Davis et al., 1989). The same applies to object-based attitudes such as information and system satisfaction deployed in the updated ISSM as well (Ajzen & Fishbein, 2005; Davis et al., 1989; DeLone & McLean, 2003).

Consequently, the first steps towards the amalgamation of both research streams are provided, and they are presumed and proven to remedy the respective drawbacks of the TAM and the ISSM (e.g. Wixom & Todd, 2005).

According to the present literature review, the majority of the studies found is either based on one of these research streams (e.g. Holsapple & Lee-Post, 2006; Lee, 2006) or on amalgamations of both of them (e.g. Liaw & Huang, 2003).

Amalgamations of the TAM and/or the ISSM with further research streams such as the diffusion of innovations theory (Rogers, 1995) are used less frequently (e.g. Chang & Tung, 2008). This initially underlines the dominant positions of the TAM and the ISSM (also) in research concerning VLE design characteristics.

[2] The studies of this literature review are separately indicated with an asterisk (*) in the references.

Table 1
Studies concerning design characteristics of VLE: overview.

Study	Theoretical foundation			Range of validity	Definition	Data gathering and analysis method	Data Source	Design characteristic	
	ISSM	TAM	Other					*System-related*	*Information-related*
1. Liaw & Huang (2003)	X	X		Universal		Offline survey, Multiple regression analysis	Single domain	System quality	–
2. Chiu et al. (2005)			X	Universal	X	Survey with application, AMOS/LISREL	Single domain	Perceived usability	Perceived quality
3. Liaw et al. (2006)	X	X		Contingent		Offline survey, Multiple regression analysis	Single domain	System quality	–
4. Roca et al. (2006)	X	X	X	Universal	X	Online survey with application, AMOS/LISREL	Different domains	System quality	Information quality
5. Lee (2006)		X		Contingent		Online survey with application, Regression analysis	Different domains	–	Perceived content quality, Course attributes
6. Holsapple & Lee-Post (2006)	X			Universal		Survey with prototype and application, Percentage distribution	Single domain	System quality	Information quality
7. Lin (2007)	X			n/a	X	Offline survey with application, Confirmatory factor analysis	Single domain	System quality	Information quality
8. Yeung & Jordan (2007)	X	X	X	n/a		Offline survey with application, AMOS/LISREL	Different domains	System quality	Information quality
9. Wang et al. (2007)	X			Universal		Evaluation of an application, Exploratory factor analysis	Different domains	System quality	Information quality
10. Poelmans, Wessa, Mills,Bloemen, & Doom (2008)	X	X		Universal	X	Offline survey with application, PLS	Single domain	System quality	Information quality
11. Chang & Tung (2008)		X	X	Contingent		Survey with application, AMOS/LISREL	Different domains	Perceived System quality	–
12. Mueller & Zimmermann, (2009)	X	X		Contingent universal		Conceptual	–	System quality	Information quality
13. Wang & Wang (2009)	X	X		n/a	X	Online survey, AMOS/LISREL	Different domains	System quality	Information quality
14. Tobing et al. (2008)		X		Contingent		Offline experiment with application, Regression analysis	Single domain	System adaptability	–
15. Arbaugh (2000)		X		Contingent		Offline and Online survey with application, Regression analysis	Single domain	Perceived course interaction, Perceived flexibility(time, location, methods)	
16. Hong et al. (2001–2002)		X		Contingent	X	Telephone/Online interview with application, AMOS/LISREL	Single domain	Screen design	Relevance, Terminology
17. Wang (2003)			X	Contingent universal		Interview and Survey with application, Exploratory factor analysis	Different Domains	Learner interface Learning community Personalisation Content	
18. Liu, Liao, & Peng (2005)		X	X	Contingent		Survey with application, One-way-ANOVA	Single domain	–	eLearning Materials Presentation Types:1. Text-Audio,2. Audio-Video,3. Text-Audio-Video
19. Lee et al. (2005)		X		Contingent	X	Evaluation of an application, Multiple regression analysis	Different domains	Screen design, Navigation	Terminology
20. Pituch & Lee (2006)		X		Contingent	X	Offline experiment with application, AMOS/LISREL	Single domains	System functionality, System interactivity, System response	–
21. Fu et al. (2007)		X		Contingent universal		Online survey with application, AMOS/LISREL	Single domains	System functionality, Interface design	–
22. Sun et al. (2008)			X	Contingent	X	Online survey with application, Regression analysis	Different domains	Course flexibility(time, location, methods) Technology quality Course quality	
23. Martínez-Torres et al. (2008)		X		n/a		Survey with application, PLS	Single domain	Accessibility, Communicativeness, Feedback, Interactivity and Control, Reliability, User adaptation, User tools Format	
24. Sahin & Shelley (2008)		X		n/a		Online survey with application, AMOS/LISREL	Single domain	Flexibility	–

Table 1 (*continued*)

Study	Theoretical foundation			Range of validity	Definition	Data gathering and analysis method	Data Source	Design characteristic
	ISSM	TAM	Other					*System-related* *Information-related*
25. Nov & Ye (2008)	X			Contingent	X	Offline survey with application, Regression analysis	Single domain	Screen design Relevance
26. Arbaugh (2002)		X		Contingent	X	Offline and Online survey with application, Hierarchical regression Analysis	Single Domain	Course flexibility (time, location, methods) Program flexibility(time, location, methods) –
27. Cho et al. (2009)	X	X		Contingent universal	X	Offline survey with application, AMOS/LISREL	Different domains	Perceived UI design Perceived functionality –
28. Johnson et al. (2009)		X		Universal	X	Online survey with application, Multiple regression analysis	Single domain	Media synchronicity –
29. Thong et al. (2002)	X			Contingent	X	Telephone/Online interview with application, Multiple Regression Analysis	Single domain	Screen design navigation Terminology relevance
30. Wu et al. (2008)	X			Contingent universal	X	Online survey with application, PLS	Different domains	System functionality Content feature

Thus, the studies almost entirely focus on the individual level of analysis (Grover, Jeong, & Segars, 1996), whereby predominantly considering a learner-/VLE user-centred evaluation perspective (Wang & Wang, 2009 is the sole study focused on a learning supporter-centred evaluation perspective).

There is no surprise that these foundations are often of central importance for the derivation of VLE design characteristics. For instance, the frequently detectable combination of *system quality* and *information quality* as relevant VLE design characteristics is a direct result of the ISSM used for founding the corresponding studies (e.g. Lin, 2007). Contrarily, and as distinct from ISSM-founded VLE design characteristics, most of the VLE design characteristics used in relation to the TAM lack a proper derivation from, and direct connection to, this theoretical foundation. This is mainly caused by the global *systems characteristics* category applied as external variable to the TAM which, however, is not further specified and subdivided into consistently applied sub-categories such as *system-* and/or *information quality*.

4.3. Range of validity

The range of validity of VLE design characteristics turns out to be quite diverse. Whereas there exists an imbalance in favour of the studies applying design characteristics contingent on VLE (Mueller et al., 2010; see Table 3), these design characteristics originate either directly in the VLE design characteristics literature pool available or they are own-developed by drawing back on relevant VLE literature (e.g. Dillon, Hengst, & Zoller, 1991; Sherwood, Armstrong, & Bond, 1994; Thach & Murphy, 1995).

As distinct from VLE design characteristics drawn from studies in the same context (e.g. Hong et al., 2001–2002; Pituch & Lee, 2006; Thong, Hong, & Tam, 2002; Wang, 2003), and thus, considered to be contingent on VLE in particular (Mueller et al., 2010), universal ones are found to be drawn from the following contexts (see Table 3): data warehouse (Wixom & Todd, 2005), e-commerce (e.g. Molla & Licker, 2001) or IS in general (e.g. McKinney, Yoon, & "Mariam" Zahedi, 2002).

However, the unreflective recourse to universal VLE design characteristics may prevent researchers from specifying, eliciting and evaluating design characteristics relevant to the success of VLE adequately so that practitioners may be jeopardised not to develop, implement and/or evaluate VLE successfully (Mueller et al., 2010). This is in concert with substantial literature on IS success that recommends the selection of IS success dimensions and measures to be contingent on the objectives and context of the empirical investigation at hand (DeLone & McLean, 2003).

Thus, researchers are called upon to agree on the core set of system- and information-related design characteristics which determine VLE success in general. Subsequently, a consensus about system- and information-related design characteristics per VLE sub-category (e.g. adaptive learning environments) should be achieved to fit better the specifics of particular VLE contexts. At the same time, such a consensus may refine and further drive the agreement upon a universally applicable core set of design characteristics to the entire VLE category.

On the basis of such knowledge, corresponding VLE evaluation results can be better compared and validated with a view to a) other system categories such as data warehouse or e-commerce applications, or (specific sub-types of) VLE solely (DeLone & McLean, 2003).

Table 2
Theoretical foundation.

Theoretical foundation	Study
ISSM	Holsapple & Lee-Post, 2006; Liaw & Huang, 2003; Liaw et al., 2006; Lin, 2007; Mueller & Zimmermann, 2009; Poelmans et al., 2008; Roca et al., 2006; Wang & Wang, 2009; Wang et al., 2007; Yeung & Jordan, 2007
TAM	Arbaugh, 2000; Chang & Tung, 2008; Cho et al., 2009; Fu et al., 2007; Hong et al., 2001–2002; Lee, 2006; Lee et al., 2005; Liaw & Huang, 2003; Liaw et al., 2006; Liu et al., 2005; Martínez-Torres et al., 2008; Mueller & Zimmermann, 2009; Nov & Ye, 2008; Pituch & Lee, 2006; Poelmans et al., 2008; Roca et al., 2006; Sahin & Shelley, 2008; Sun et al., 2008; Thong et al., 2002; Tobing et al., 2008; Wang & Wang, 2009; Wu et al., 2008; Yeung & Jordan, 2007

Table 3
Range of validity.

Range of validity and original context	Study
Contingent	Arbaugh, 2000, 2002; Chang & Tung, 2008; Hong et al., 2001–2002; Lee, 2006; Lee et al., 2005; Liaw et al., 2006; Mueller & Zimmermann, 2009; Nov & Ye, 2008; Pituch & Lee, 2006; Sun et al., 2008; Thong et al., 2002; Tobing et al., 2008; Wang et al., 2007; Wu et al., 2008
Universal	
Data warehouse	Mueller & Zimmermann, 2009
e-Commerce	Wu et al., 2008
IS in general	Chiu et al., 2005; Holsapple & Lee-Post, 2006; Mueller & Zimmermann, 2009; Poelmans et al., 2008; Roca et al., 2006

4.4. Definition

Unfortunately, there is a prevalent lack of explicit definitions of VLE design characteristics presented (see Table 4).

Since design characteristics such as *system flexibility* (e.g. Sahin & Shelley, 2008) regularly represent rather complex constructs which can be understood in quite different ways, this lack of definition aggravates the understanding of VLE design characteristics as well as their further usage.

This also complicates the detection of possible redundancies of characteristics found in different studies such as *system flexibility* (e.g. Sahin & Shelley, 2008) and *system adaptability* (Tobing et al., 2008).

4.5. Data gathering method

As Table 5 shows, the main data gathering method applied constitutes offline and/or online surveys with final applications, whereas some studies do not further specify the channel (i.e. offline vs. online) applied (e.g. Chang & Tung, 2008). However, the studies that are being discussed lack data gathering methods such as Delphi studies and experiments even though these data gathering methods are considered to constitute a promising and valuable means to comprehensively evaluate, respectively, prioritise design characteristics relevant to VLE success (Mueller & Strohmeier, 2010; Mueller et al., 2010; see for example the pioneering work of Pituch & Lee (2006) and Tobing et al. (2008) who conducted an offline experiment and application).

To be more precise (see Table 6), only 12 studies gather data originating in a single application domain (e.g. based on one particular university), whereas the remaining studies gather data through different application domains (e.g. through different international agencies/organisations (e.g. Wang et al., 2007), class sections (Arbaugh, 2002), companies (Yeung & Jordan, 2007) or universities (e.g. Wang & Wang, 2009)). Schools as a prominent VLE application domain cannot be found in relation to the particular scope of this study.

4.6. Data analysis method

With a view to the data analysis method applied (see Table 7), the focal point of this literature review lies on empirical methods, whereas the main data analysis methods applied turns out to be (multiple) regression analysis as well as structural equation modeling (SEM). Thereby, covariance-based approaches such as AMOS/LISREL are favoured opposed to variance-based approaches such as Partial Least Squares (PLS).

This is in line with the previous statements which underline that "[…] by far the most common approach for SEM has been covariance-based procedures. Yet, the PLS procedure may be more suitable under certain circumstances" (Chin & Newsted, 1999, p. 337). In particular, covariance-based approaches are applied preferably to confirm or reject theoretically-founded (inter-)relationships based on the TAM and/or the ISSM, among others (e.g. Chin & Newsted, 1999). Component-/variance-based approaches such as PLS expand the scope of application of the former ones. That is, PLS supports research in exploring, respectively, predicting hitherto undiscovered (inter-)relationships of VLE design characteristics and further dependent variables inherent, for instance, to the ISSM (e.g. *information* and *system quality*). The same applies to complex research models originated in promising amalgamations of the TAM and the ISSM, among others (e.g. Chin, 1998; Henseler, Ringle, & Sinkovics, 2009).

4.7. VLE design characteristics

The VLE design characteristics identified are of different granularities since quite coarse-granular, more general, characteristics such as *system quality* and rather medium-granular, more specific, characteristics such as *system adaptability* can be differentiated. It is obvious, the expressiveness and operativeness of design characteristics increases with growing specificity (as, for instance, "design/ensure *adaptable* VLE" constitutes a more expressive and usable statement than "design/ensure VLE with high *system quality*"). However, growing specificity is commonly aligned with a decreasing range of validity. Referring to this, the set of coarse-granular design characteristic is very small, while conversely there is a plethora of different medium-granular design characteristics. Fine-granular design characteristics cannot be detected. Table 1 hence roughly differentiates studies with coarse-granular (# 1–14) and medium-granular (# 15–30) design characteristics.

Table 4
Definition.

Existence of a definition	Study
Yes	Arbaugh, 2002; Chiu et al., 2005; Cho et al., 2009; Hong et al., 2001–2002; Johnson et al., 2009; Lee et al., 2005; Lin, 2007; Nov & Ye, 2008; Pituch & Lee, 2006; Poelmans et al., 2008; Roca et al., 2006; Sun et al., 2008; Thong et al., 2002; Tobing et al., 2008; Wang & Wang, 2009; Wu et al., 2008
No	Arbaugh, 2000; Chang & Tung, 2008; Fu et al., 2007; Holsapple & Lee-Post, 2006; Lee, 2006; Liaw & Huang, 2003; Liaw et al., 2006; Liu et al., 2005; Martínez-Torres et al., 2008; Mueller & Zimmermann, 2009; Sahin & Shelley, 2008; Wang et al., 2007; Wang, 2003; Yeung & Jordan, 2007

Table 5
Data gathering method.

Data gathering method	Study
Offline survey	Liaw & Huang, 2003; Liaw et al., 2006
Online survey	Wang & Wang, 2009
Offline survey with application	Cho et al., 2009; Lin, 2007; Nov & Ye, 2008; Poelmans et al., 2008; Yeung & Jordan, 2007
Online survey with application	Fu et al., 2007; Johnson et al., 2009; Lee, 2006; Roca et al., 2006; Sun et al., 2008; Wu et al., 2008
Offline and Online survey with application	Arbaugh, 2000; Arbaugh, 2002
Survey with application	Chang & Tung, 2008; Chiu et al., 2005; Liu et al., 2005; Martínez-Torres et al., 2008; Sahin & Shelley, 2008
Survey with prototype and application	Holsapple & Lee-Post, 2006
Offline experiment with application	Pituch & Lee, 2006; Tobing et al., 2008
Telephone/Online interview with application	Hong et al., 2001–2002; Thong et al., 2002
Interview and survey with application	Wang, 2003
Evaluation of an application	Lee et al., 2005; Wang et al., 2007

In particular, there are only a few coarse-granular design characteristic such as the repeatedly presented *(perceived) system quality* (e.g. Wang & Wang, 2009) and *information quality* (e.g. Roca, Chiu, & Martínez, 2006). Three studies also directly reveal *content feature/quality and course quality* as general information-related VLE design characteristics (Sun et al., 2008).

As opposed to coarse-granular VLE design characteristics, a plethora of medium-granular design characteristics is offered.

System-related design characteristics found are *accessibility*, *communicativeness*, *feedback* (Martínez-Torres et al., 2008), respectively, *system response* (e.g. Pituch & Lee, 2006) and *interface/screen design* (e.g. Cho et al., 2009). Beyond, *learning community* (Wang, 2003), *navigation* (Lee, Dahlan, Ramayah, Karia, & Hasmi Abu Hassan Asaari, 2005), *system flexibility* (e.g. Sun et al., 2008), respectively, *media synchronicity* (Johnson et al., 2009) and *interaction/interactivity (and control)* (e.g. Martínez-Torres et al., 2008) can be revealed. Finally, *system functionality* (e.g. Wu et al., 2008), respectively *user tools* (Martínez-Torres et al., 2008), *usability* (Chiu et al., 2005), *personalisation* (Wang, 2003), respectively, *user adaptation* (Martínez-Torres et al., 2008) and *system adaptability* (Tobing et al., 2008) as well as *reliability* (Martínez-Torres et al., 2008) are carved out.

Information-related design characteristics are *course quality* (Sun et al., 2008), *format* (Martínez-Torres et al., 2008), *material presentation type* (Hong et al., 2001–2002), *course attributes* (Lee, 2006), *relevance* (e.g. Nov & Ye, 2008), and *terminology* (e.g. Hong et al., 2001–2002).

Therewith, a lot of different VLE design characteristics of mixed granularities are offered although there is a rather limited agreement between the studies on the core set of design characteristics relevant to the success of VLE.

Thus, Table 8 focuses on such coarse- and medium-granular system- and information-related VLE design characteristics that prove empirically a significant influence on particular (dependent) VLE success variables. This is due to the fact that only such design characteristics can support practitioners in developing, implementing and improving/evaluating VLE successfully (Mueller et al., 2010). Hence, Table 8 illustrates "the" important VLE design characteristics elicited by means of this literature review. The potential, respectively, actual ability of these design characteristics to impact promising VLE success variables as listed in Table 8 is expressed by their effect strengths and levels of significance found in the corresponding studies:

Thereby, based on the wide application of the TAM and the ISSM, VLE success variables mainly originate in one of these theories. In particular, most studies investigate the influence of coarse- and medium-granular VLE design characteristics on either coarse-granular (e.g. users' behavioural intention to use, actual use of, satisfaction with, and [perceived] net benefits of using a VLE) or medium-granular (e.g. enjoyment) success variables. Thus, the VLE design characteristics applied are not limited exclusively to a single overall construct such as *system* or *information quality* to subsume specific VLE design characteristics such as *system flexibility* or *system interactivity* (e.g. Wang & Wang, 2009). Regarding "the" two prominent theoretical foundations of VLE design characteristics this implies the following: the TAM and the ISSM propose, at least, rough VLE design guidelines that have the potential to impact VLE success. This is, in turn, mainly due to the fact that the TAM mediates the effect of VLE design characteristics on users' behavioural intention to use, respectively, their actual use of a VLE (Davis, 1989; Davis et al., 1989). The same applies to the updated ISSM which is thought to mediate the influence of VLE design characteristics on users' (perceived) net benefits of using a VLE (DeLone & McLean, 1992, 2003).

With a particular view to empirically proven interdependencies between specific VLE design characteristics, only two studies investigate such interrelationships, and thus potential bundles/entire configurations of VLE design characteristics (Cho et al., 2009; Martínez-Torres et al., 2008). For example, *interface*, respectively, *screen design* is found to show an impact on users' perceived *functionality* of a VLE (Cho et al., 2009). That is, the better the visual appeal of the VLE's graphical user interface is, the more users perceive the VLE to exhibit appropriate system functionalities. However, additional research into interdependencies between specific VLE design characteristics is needed to (further) verify potential (in-)compatibilities amongst them (Galletta & Lederer, 1989). At the same time further research is required to investigate which of these VLE design characteristics elicited do contribute to VLE success independently, or interdependently, i.e. in the shape of a bundle/entire configuration.

In order to better exemplify the potential impact of these initial findings on practitioners' development, implementation and/or improvement/evaluation of specific VLE, the subsequent elaboration outlines potential application scenarios to demonstrate how to deal

Table 6
Data source.

Data source	Study
Single domain	Arbaugh, 2000; Arbaugh, 2002; Chiu et al., 2005; Fu et al., 2007; Holsapple & Lee-Post, 2006; Hong et al., 2001–2002; Johnson et al., 2009; Liaw & Huang, 2003; Liaw et al., 2006; Lin, 2007; Liu et al., 2005; Martínez-Torres et al., 2008; Nov & Ye, 2008; Pituch & Lee, 2006; Poelmans et al., 2008; Sahin & Shelley, 2008; Thong et al., 2002; Tobing et al., 2008
Different domains	Chang & Tung, 2008; Cho et al., 2009; Lee, 2006; Lee et al., 2005; Roca et al., 2006; Sun et al., 2008; Wang, 2003; Wang & Wang, 2009; Wang et al., 2007; Wu et al., 2008; Yeung & Jordan, 2007

Table 7
Data analysis method.

Data analysis method	Study
Exploratory factor analysis	Wang, 2003; Wang et al., 2007
Regression analysis	Arbaugh, 2000; Lee, 2006; Nov & Ye, 2008; Tobing et al., 2008; Sun et al., 2008
Hierarchical regression analysis	Arbaugh, 2002
Multiple regression analysis	Johnson et al., 2009; Lee et al., 2005; Liaw & Huang, 2003; Liaw et al., 2006; Thong et al., 2002
SEM	
PLS	Martínez-Torres et al., 2008; Poelmans et al., 2008; Wu et al., 2008
AMOS/LISREL	Chang & Tung, 2008; Chiu et al., 2005; Cho et al., 2009; Fu et al., 2007; Hong et al., 2001–2002; Lin, 2007; Pituch & Lee, 2006; Roca et al., 2006; Sahin & Shelley, 2008; Wang & Wang, 2009; Yeung & Jordan, 2007

with "the" important VLE design characteristics (see Table 8). At the same time this may stimulate the creation of new (conceptual/empirical/theoretical) knowledge which may unfold or verify the actual ability of these characteristics on VLE success in a real-world application scenario. For example, in order to evaluate users' perceptions of a VLE's learning process management component researchers may draw back on the well-known, coarse-granular VLE design characteristic *system quality*. However, the expressiveness and operativeness of this design characteristic is of limited nature ("design/ensure a VLE learning process management component with high *system quality*"). Hence, the application of the medium-granular VLE design characteristic *system flexibility* could be a way out of this dilemma ("design/ensure a *flexible* VLE learning process management component"). However, *flexible*, in turn, is conceptualised to further conflate *adaptive* (i.e. "design/ensure an automated personalisation of the learning process via the VLE itself") and *adaptable* (i.e. "design/ensure a manual customisation of the learning process via the VLE user her-/himself") components in order to reflect system- and VLE user-driven adjustments of the learning process itself as well as the learning resources inherent to it (e.g. Martínez-Torres et al., 2008; Mueller & Strohmeier, 2010; Sahin & Shelley, 2008; Tobing et al., 2008).

In accordance with Höök (1997), this implies the following: users should always have the "*control* of the [VLE system] *adaptivity* and be able to alter the assumptions made by the system" as "a problem with adaptive systems in general […] is that they might make wrong adaptations based on guesses […]" (Höök, 1997, p. 180), i.e., a VLE's learning process management component should be always both *adaptive* and *adaptable* in order to be perceived as *flexible*.

Such a *system flexibility*, in turn, may further impact users' perceived VLE *system quality* and VLE success positively (e.g. users' behavioural intention to use this VLE).

Hence, even though fine-granular design characteristics cannot be detected, one may, in general, conceptualise (VLE) design characteristics as multi-level constructs ranging from fine- to medium- and course-granular characteristics ("three-level construction of [VLE] design characteristics"). For example, *system adaptability*, respectively (*system interactivity* and), *control* as well as *user adaptation* could be modeled as sub-facets (level 1) of *system flexibility* (level 2), which, in turn, would drive *system quality* as an overall, cohesive element (level 3). The same may apply to *communicativeness*, *feedback*, and *system response* as imaginable sub-characteristics of *system interactivity* (and *control*), which, in turn, may have a significant impact on *system quality*. This presumption is due to the fact that *interactive* itself is conceptualised to allow for learner-system-, learner-learner-, and/or learner-teacher-communication/-collaboration by means of a variety of the so-called learning tools like chats, blogs or video conference facilities (Mueller & Strohmeier, 2010). *System quality*, as an overall umbrella of the aforementioned sub-characteristics, may then influence desired VLE success variables such as users' behavioural intention to use, actual use of, satisfaction with, and (perceived) net benefits of using a VLE.

In summary it can be stated that VLE design characteristics described in previous studies are

- often, but not always derived from adequate theories;
- universally applicable to VLE in general;
- often unclear in meaning, and hence of somewhat restricted expressiveness and operational capability;
- predominantly evaluated via offline and/or online surveys with applications and analysed by use of multiple regression analysis as well as SEM;
- mostly evaluated in a single application domain;
- of different granularity, and hence of different expressiveness and usability;
- abundant, but of limited congruence, systematic, and completeness.

The above-mentioned results should generally provide a basic starting point for future research as design endeavours because there are some implications for research and practice.

5. Implications

5.1. Implications for research

Concerning implications for research the following can be stated: generally, further theoretical deliberations may improve future research. In particular, the ISSM is able to categorise roughly relevant VLE design characteristics, but, however, does not allow for deducing specific VLE design characteristics of finer granularity directly. This obviously applies to further imaginable theoretical foundations likewise, in particular, to the prominent TAM approach that can be demonstrated within the frame of the literature review (e.g. Roca et al., 2006). Thus, future research should keep working on, and refining promising theoretical amalgamations of the TAM and the ISSM whilst drilling

Table 8
VLE design characteristics.

Design characteristic and result			Study
Design characteristic	(Dependent) Success variable	Effect strength and level of significance (Sign.)	
A) System-related			
Communicativeness	User adaptation	0.75***	Martínez-Torres et al., 2008
Feedback	Interactivity and Control	0.53***	Martínez-Torres et al., 2008
Media synchronicity	Course satisfaction	0.26**	Johnson et al., 2009
(Perceived Course/Program/System) Flexibility	PU	0.57**	Sahin & Shelley, 2008
	(Course) Satisfaction	0.13**	Arbaugh, 2000
		0.46***	Arbaugh, 2000
		0.30***	Arbaugh, 2002
		0.35**	Sahin & Shelley, 2008
		0.08*	Sun et al., 2008
Perceived quality	Satisfaction	0,21*	Chiu et al., 2005
Perceived usability	Satisfaction	0.15*	Chiu et al., 2005
(Perceived user) Interface/Screen design	PEOU	0.55***	Cho et al., 2009
		0.34***	Fu et al., 2007
		0.29***	Hong et al., 2001–2002
		0.22**	Nov & Ye, 2008
	Perceived functionality	0.69***	Cho et al., 2009
(Perceived) System functionality	PEOU	0.16*	Fu et al., 2007
		0.17*	Pituch & Lee, 2006
	PU	0.47***	Cho et al., 2009
		0.16*	Wu et al., 2008
Reliability	PEOU	0.41***	Martínez-Torres et al., 2008
(System) Accessibility	PEOU	0.29***	Martínez-Torres et al., 2008
		0.26**	Thong et al., 2002
System adaptability	PEOU	0.64*	Tobing et al., 2008
	PU	0.66*	Tobing et al., 2008
System interactivity (and control)	PU	0.23*	Martínez-Torres et al., 2008
		0.38*	Pituch & Lee, 2006
System quality	BI	0.13*	Chang & Tung, 2008
		0.13*	Lin, 2007
		0.27**	Poelmans et al., 2008
	PEOU	0.59**	Poelmans et al., 2008
		0.23**	Wang & Wang, 2009
	Satisfaction	0.18*	Lin, 2007
		0.27**	Roca et al., 2006
		0.17*	Yeung & Jordan, 2007
System response	PEOU	0.26*	Pituch & Lee, 2006
	PU	0.21*	Pituch & Lee, 2006
User adaptation	Feedback	0.49***	Martínez-Torres et al., 2008
User tools	Enjoyment	0.22**	Martínez-Torres et al., 2008
B) Information-Related			
Content feature/Quality	PU	0.15***	Lee, 2006
		0.22***	Wu et al., 2008
Course attributes	PU	−0.06*	Lee, 2006
Course quality	Perceived e-Learner satisfaction	0.50***	Sun et al., 2008
Format	Feedback	0.34**	Martínez-Torres et al., 2008
Information quality	BI	0.33**	Lin, 2007
		0.24**	Poelmans et al., 2008
	PU	0.36***	Poelmans et al., 2008
		0.50*	Wang & Wang, 2009
	Relative advantage	0.58***	Poelmans et al. (2008)
	Satisfaction	0.42**	Lin, 2007
		0.41**	Roca et al., 2006
		0.42***	Yeung & Jordan, 2007
Information relevance	PEOU	0.14***	Hong et al., 2001–2002
		0.23**	Nov & Ye, 2008
		0.111**	Thong et al., 2002
	PU	0.61***	Hong et al., 2001–2002
		0.45**	Thong et al., 2002
Terminology (Clarity)	PEOU	0.37***	Hong et al., 2001–2002
		0.44**	Lee et al., 2005

* = sign. at $p < 0.05$, ** = sign. at $p < 0.01$, *** = sign. at $p < 0.001$ BI = users' behavioural intention to use a VLE; PEOU = users' perceived ease of use of a VLE; PU = users' perceived usefulness of a VLE.

out VLE design characteristics as well as (dependent) VLE success variables such as users' actual VLE use towards advanced levels of detailedness. This may lead towards improved levels of expressiveness and operativeness of the design characteristics and VLE success variables applied in these two theories (Wixom & Todd, 2005). At the same time such amalgamations of the TAM and the ISSM may remedy the respective drawbacks of both research streams, among them the prediction of VLE users' behavioural intention to use, respectively, actual use of a VLE as major VLE success indicator in particular (e.g. Wixom & Todd, 2005). As a consequence, more specific knowledge about design-related drivers of learners' current VLE use/refusal can be revealed so that practitioners are able to develop, implement and improve/

evaluate VLE successfully based on more explicit and thorough VLE design guidelines, respectively, corresponding VLE design interventions (e.g. Venkatesh & Bala, 2008).

Given that expressiveness and operational capability of design characteristics rise with increased granularity, future research should aim at increasing the granularity of VLE design characteristics, however, without losing general validity. Hence, further research should more concentrate on eliciting and evaluating fine- and medium-granular VLE design characteristics. One possible way is to work out different facets of VLE design characteristics by constituting multi-level constructs ranging from fine- to medium- and course-granular characteristics ("three-level construction of VLE design characteristics").

For instance, relating to certain course-granular VLE design characteristics such as *system quality*, certain related medium- (e.g. *system flexibility*) and fine-granular (e.g. *adaptive* and *adaptable*) sub-characteristics could be established in order to be compliant with the proposed "three-level construction of VLE design characteristics".

Regarding the range of validity of existing VLE design characteristics, the unreflected and often implicit recourse to universal design characteristics may overlook potential contextual contingencies of VLE design characteristics and hence prevent researchers from adequate specifying, eliciting and evaluating design characteristics relevant to the success of VLE (Mueller et al., 2010). Thus, researchers should extensively evaluate VLE design characteristics regarding their universal applicability vs. their contextual contingency.

Moreover, as VLE design characteristics prevalently suffer from a lack of explicit definitions, future work should ensure explicit and thorough definitions of VLE design characteristics.

As data gathering methods such as iterative Delphi studies and experiments are considered to constitute a promising and valuable means for comprehensive evaluation, respectively, prioritisation of design characteristics relevant to the success of VLE in particular (Mueller & Strohmeier, 2010; Mueller et al., 2010; see for example the pioneering work of Pituch and Lee (2006) and Tobing et al. (2008) who conducted an offline experiment with application), future research should apply and further investigate the benefits of such data gathering methods. At the same time it would be highly beneficial if relevant VLE design characteristics are evaluated in the early stages of the VLE development process in order to avoid costly misconceptions and failure (Davis & Venkatesh, 2004). Hence, beside particular research attempts surveying prototypes (e.g. Holsapple & Lee-Post, 2006), the usage of simple prototypical VLE models planned (e.g. paper- and/or video-based mockups/prototypes, etc.) may allow evaluating relevant VLE characteristics in the earliest phases of the corresponding VLE development, implementation and improvement process (Mueller & Strohmeier, 2010; Mueller et al., 2010; Mueller & Zimmermann, 2009). In so doing, future research should more concentrate on cross-domain data gathering efforts to make the corresponding results and, thus, implications for research and practice, more generalisable (e.g. at different companies, countries, faculties, universities, etc.).

Future research attempts should also concentrate on carving out undiscovered interrelationships between specific VLE design characteristics. The goal for that is revealing cumulative effects of specific bundles of VLE design characteristics on particular dependent VLE success variables inherent to the TAM and/or the ISSM, among others. Thereby, data analysis methods such as PLS may constitute a valuable means for researchers as it enables them to explore hitherto undiscovered (inter-)relationships amongst VLE design characteristics and further dependent variables (e.g. Henseler et al., 2009).

5.2. Implications for practice

Additionally, the results of the study yield some implications for practice. VLE-related stakeholders such as decision makers, system developers, system implementers and system evaluators are offered a general overview of system-related criteria relevant to VLE success. In compliance with the proposed "three-level construction of VLE design characteristics", ranging from fine- to medium- and course-granular characteristics, specific VLE system functionalities could be then assessed, developed and structured further on much more easily. For instance, evaluators may reveal that users do not perceive their VLE's learning process management component to exhibit high *system quality*. As the expressiveness and operativeness of the coarse-granular VLE design characteristic may be of limited nature; evaluators may drill out this initial finding by means of the more medium-granular, and, thus, more expressive and operative, VLE design characteristic *system flexibility*. The latter, more fine-granular characteristic, in turn, may be then unfolded into its *adaptive* and *adaptable* sub-facet. This way a VLE's learning process management component can be assessed to reflect system- and VLE user-driven adjustments of the learning process itself as well as the learning resources inherent to it as required (e.g. Martínez-Torres et al., 2008; Mueller & Strohmeier, 2010; Sahin & Shelley, 2008; Sun et al., 2008; Tobing et al., 2008).

At the same time careful consideration and accomplishment of each design characteristic in the proposed "three-level construction of VLE design characteristics" ensures high levels of users' perceived VLE *system quality* and, subsequently, overall VLE success.

Regarding information-related design characteristics, content providers as well as training and development-related stakeholders may profit from their application while preparing learning materials to be delivered by a VLE. The careful consideration of the proposed "three-level construction of VLE design characteristics" may facilitate these stakeholders to ensure high levels of *information quality* and, thus, overall VLE success likewise.

Hence, system- and information-related design characteristics could also be understood as a checklist to what extent the particular VLE as well as the content inherent to it fulfil the requirements elicited in the course of this study. Moreover, one should consider and ensure the compatibility between the VLE design characteristics and particular VLE stakeholder requirements to create successful VLE.

Refining and customising such a (check-)list towards individual (higher) education(al) and vocational training settings may lead to practical VLE development, implementation and improvement/evaluation processes which may minimise users' resistance to use a VLE, increase users' satisfaction with a VLE, and support overall VLE success.

6. Conclusions

A comprehensive literature review on VLE design characteristics is carried out in this paper. The review yields a comprehensive set of diverse system- and information-related VLE design characteristics as well as particular contextual information associated with them. This may contribute to a successful development, implementation and improvement/evaluation of VLE in practice. Additionally, this will hopefully stimulate future research, especially empirical studies evaluating and deepening the insights offered, but may also instruct future

practical VLE development, implementation and improvement/evaluation projects as both streams can in the end contribute to successful VLE.

Appendix. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.compedu.2011.06.017.

References

Ajzen, I., & Fishbein, M. (2005). The influence of attitudes on behavior. In D. Albarracín, B. T. Johnson, & M. P. Zanna (Eds.), *The handbook of attitudes* (pp. 173–221). Mahwah, NJ: Erlbaum.

*Arbaugh, J. B. (2000). Virtual classroom characteristics and student satisfaction with internet-based MBA courses. *Journal of Management Education, 24*(1), 32–54.

*Arbaugh, J. B. (2002). Managing the on-line classroom: a study of technological and behavioral characteristics of web-based MBA courses. *Journal of High Technology Management Research, 13*, 203–223.

Bittner, K., & Spence, I. (2003). *Use case modeling*. Boston, MA: Addison-Wesley.

*Chang, S.-C., & Tung, F.-C. (2008). An empirical investigation of students' behavioural intentions to use the online learning course websites. *British Journal of Educational Technology, 39*(1), 71–83.

Chin, W. W. (1998). Issues and opinions on structural equation modeling. *MIS Quarterly, 22*(1), 7–16.

Chin, W. W., & Newsted, P. R. (1999). Structural equation modeling analysis with small samples using partial least squares. In R. H. Hoyle (Ed.), *Statistical strategies for small sample research* (pp. 307–341). Thousand Oaks, CA: Sage.

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

*Cho, V., Cheng, E. T. C., & Lai, J. W. M. (2009). The role of perceived user-interface design in continued usage intention of self-paced e-learning tools. *Computers & Education, 53*(2), 216–227.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Davis, F. D. (1993). User acceptance of information technology: system characteristics, user perception and behavioral impact. *International Journal of Man-Machine-Studies, 38*(3), 475–487.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management Science, 35*, 982–1003.

Davis, F. D., & Venkatesh, V. (2004). Toward preprototype user acceptance testing of new information systems: implications for software project management. *IEEE Transactions on Engineering Management, 51*(1), 31–46.

DeLone, W. H., & McLean, E. R. (1992). Information systems success: the quest for the dependent variable. *Information Systems Research, 3*(1), 60–95.

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: a ten-year update. *Journal of Management Information Systems, 19*(4), 9–30.

Dennis, A. R., Wixom, B. H., & Roth, R. M. (2006). *Systems analysis and design*. Hoboken: John Wiley & Sons.

Dillon, C. L., Hengst, H. R., & Zoller, D. (1991). Instructional strategies and student involvement in distance education: a study of the Oklahoma televised instruction system. *Journal of Distance Education, 6*(1), 28–41.

Doty, D. H., & Glick, W. H. (1994). Typologies as a unique form of theory building: towards improved understanding and modeling. *Academy of Management Review, 19*(2), 230–251.

Fry, H., Ketteridge, S., & Marshall, S. (2009). *A handbook for teaching and learning in higher education: Enhancing academic practice*. New York: Routledge.

*Fu, F.-L., Chou, H.-G., & Yu, S.-C. (2007). Activate interaction relationships between students acceptance behavior and e-learning. In G. Dong, X. Lin, W. Wang, Y. Yang, & J. Xu Yu (Eds.), *Proceedings of the joint 9th Asia-Pacific Web Conference and 8th International Conference on Web-Age Information Management* (pp. 670–677). Berlin & Heidelberg: Springer.

Galletta, D. F., & Lederer, A. L. (1989). Some cautions on the measurement of user information satisfaction. *Decision Sciences, 20*(3), 419–439.

Grover, V., Jeong, S. R., & Segars, A. H. (1996). Information systems effectiveness: the construct space and patters of application. *Information & Management, 31*(4), 177–191.

Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. *Advances in International Marketing, 20*, 277–319.

*Holsapple, C. W., & Lee-Post, A. (2006). Defining, assessing, and promoting e-learning success: an information systems perspective. *Decision Sciences Journal of Innovative Education, 4*(1), 67–85.

*Hong, W., Thong, J. Y. L., Wong, W.-M., & Tam, K.-Y. (2001–2002). Determinants of user acceptance of digital libraries: an empirical examination of individual differences and system characteristics. *Journal of Management Information Systems, 18*(3), 97–124.

Höök, K. (1997). Evaluating the utility and usability of an adaptive hypermedia system. In J. Moore, E. Edmonds, & A. Puerta (Eds.), *Proceedings of the second international conference on Intelligent user interfaces* (pp. 179–186), Retrieved from. http://delivery.acm.org/10.1145/240000/238320/p179-hook.pdf?key1=238320&key2=8247564921&coll=DL&dl=ACM&CFID=5556663&CFTOKEN=57778474 [last accessed June 2011].

Hornik, S., Johnson, R. D., & Wu, Y. (2007). When technology does not support learning: conflicts between epistemological beliefs and technology support in virtual learning environments. *Journal of Organizational and End User Computing, 19*(2), 23–46.

ISO. (1999). *ISO 13407: Human-centred design processes for interactive systems*. Retrieved from. http://www.iso.org/iso/catalogue_detail.htm?csnumber=21197 [last accessed June 2011].

ISO. (2005). *ISO/IEC 25000: Software product quality requirements and evaluation (SQuaRE)*. Retrieved from. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=35683 [last accessed June 2011].

*Johnson, R. D., Gueutal, H., & Falbe, C. M. (2009). Technology, trainees, metacognitive activity and e-learning effectiveness. *Journal of Managerial Psychology, 24*(6), 545–566.

Kavanagh, M. J., & Thite, M. (2009). *Human resource information systems: Basics, applications, and future directions*. Los Angeles: Sage.

Kuechler, W., & Vaishnavi, V. (2008). The emergence of design research in information systems in North America. *Journal of Design Research, 7*(1), 1–16.

*Lee, G. T., Dahlan, N., Ramayah, T., Karia, N., & Hasmi Abu Hassan Asaari, M. (2005). Impact of interface characteristics on digital libraries usage. *Malaysian Online Journal of Instructional Technology, 2*(1), 1–9.

*Lee, Y.-C. (2006). An empirical investigation into factors influencing the adoption of an e-learning system. *Online Information Review, 30*(5), 517–541.

*Liaw, S.-S., Chang, W.-C., Hung, W.-H., & Huang, H.-M. (2006). Attitudes toward search engines as a learning assisted tool: approach of Liaw and Huang's research model. *Computers in Human Behavior, 22*, 177–190.

*Liaw, S.-S., & Huang, H.-M. (2003). An investigation of user attitudes toward search engines as an information retrieval tool. *Computers in Human Behavior, 19*, 751–765.

*Lin, H.-F. (2007). Measuring online learning systems success: applying the updated DeLone and McLean model. *Cyber Psychology & Behavior, 10*(6), 817–820.

*Liu, S.-H., Liao, H.-L., & Peng, C.-J. (2005). Applying the technology acceptance model and flow theory to online e-learning users' acceptance behavior. *Issues in Information Systems, 6*(2), 175–181.

*Martínez-Torres, M. R., Toral Marín, S. L., Barrero Garciá, F., Gallardo Váquez, S., Arias Oliva, M., & Torres, T. (2008). A technological acceptance of e-learning tools used in practical and laboratory teaching, according to the European higher education area. *Behaviour & Information Technology, 27*(6), 495–505.

McKinney, V., Yoon, K., & "Mariam" Zahedi, F. (2002). The measurement of web-customer satisfaction: an expectation and disconfirmation approach. *Information Systems Research, 13*(3), 296–315.

Molla, A., & Licker, P. S. (2001). E-commerce systems success: an attempt to extend and respecify the DeLone & McLean model of IS success. *Journal of Electronic Commerce Research, 2*(4), 1–11.

Mueller, D., & Strohmeier, S. (2010). Design characteristics of virtual learning environments: an expert study. *International Journal of Training and Development, 14*(3), 209–222, (accepted).

Mueller, D., Strohmeier, S., & Gasper, C. (2010). HRIS design characteristics: towards a general research framework. In S.Strohmeier., & A. Diederichsen. (Eds.), *Proceedings of the third European Academic Workshop on electronic Human Resource Management* (pp. 250–267), Retrieved from. http://CEUR-WS.org/Vol-570/ [last accessed June 2011].

*Mueller, D., & Zimmermann, V. (2009). A learner-centered design, implementation, and evaluation approach of learning environments to foster acceptance. *International Journal of Advanced Corporate Learning, 2*(3), 50–57.

*Nov, O., & Ye, C. (2008). Users' personality and perceived ease of use of digital libraries: The case for resistance to change. *Journal of the America Society for Information Science and Technology, 59*(5), 845–851.
Ozkan, S., & Koseler, R. (2009). Multi-dimensional students' evaluation of e-learning systems in the higher education context: an empirical investigation. *Computers & Education, 53*(4), 1285–1296.
Piccoli, G., Ahmad, R., & Ives, B. (2001). Web-based virtual learning environments: a research framework and a preliminary assessment of effectiveness in IT skills training. *MIS Quarterly, 25*(4), 401–426.
*Pituch, K. A., & Lee, Y.-K. (2006). The influence of system characteristics on e-learning use. *Computers & Education, 47*, 222–244.
*Poelmans, S., Wessa, P., Mills, K., Bloemen, E., & Doom, C. (2008). Usability and acceptance of e-learning in statistics education, based on the compendium platform. In *Proceedings of the International Conference of Education, Research and Innovation* (pp. 1–10), Retrieved from. http://www.wessa.net/download/iceripaper1.pdf [last accessed June 2011].
*Roca, J. C., Chiu, C.-M., & Martínez, F. J. (2006). Understanding e-learning continuance intention: an extension of the technology acceptance model. *International Journal of Human-Computer Studies, 64*, 683–696.
Rogers, E. M. (1995). *The diffusion of innovations*. New York: Free Press.
*Sahin, I., & Shelley, M. (2008). Considering students' perceptions: The distance education student satisfaction model. *Educational Technology & Society, 11*(3), 216–223.
Seddon, P. B. (1997). A respecification and extension of the DeLone and McLean model of IS success. *Information Systems Research, 8*(3), 240–253.
Seddon, P. B., Graeser, V., & Wilcocks, L. P. (2002). Measuring organizational IS effectiveness: an overview and update of senior management perspectives. *The DATA BASE for Advances in Information Systems, 33*(2), 11–28.
Seddon, P. B., Staples, S., Patnayakuni, R., & Bowtell, M. (1999). Dimensions of information systems success. *Communications of the AIS, 2*, 1–60.
Sherwood, G. D., Armstrong, M. L., & Bond, M. L. (1994). Distance education programs: defining issues of assessment, accessibility, & accommodation. *Journal of Continuing Education in Nursing, 25*(6), 251–257.
Sitzmann, T., Kraiger, K., Stewart, D., & Wisher, R. (2006). The comparative effectiveness of web-based and classroom instruction: a meta-analysis. *Personnel Psychology, 59*, 623–664.
Sommerville, I. (2007). *Software engineering*. Harlow: Addison-Wesley.
Strohmeier, S. (2008). *Informationssysteme im Personalmanagement: Architektur – Funktionalität – Anwendung*. Wiesbaden: Vieweg+Teubner.
*Sun, P.-C., Tsai, R. J., Finger, G., Chen, Y.-Y., & Yeh, D. (2008). What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education, 50*, 1183–1202.
Thach, E. C., & Murphy, K. L. (1995). Competencies for distance education professionals. *Educational Technology Research & Development, 43*(1), 57–79.
*Thong, J. Y. L., Hong, W., & Tam, K.-Y. (2002). Understanding user acceptance of digital libraries: what are the roles of interface characteristics, organizational context, and individual differences? *International Journal of Human-Computer Studies, 57*(3), 215–242.
*Tobing, V., Hamzah, M., Sura, S., & Amin, H. (2008). Assessing the acceptability of adaptive e-learning system. In *Proceedings of the 5th International Conference on eLearning for Knowledge-Based Society* (pp. 1–10), Retrieved from. http://www.ijcim.th.org/v16nSP3/13_fullpaper_Vianny%20Tobing_Revised.pdf [last accessed June 2011].
Van Aken, J. E. (2005). Management research as a design science: articulating the research products of mode 2 knowledge production in management. *British Journal of Management, 16*(1), 19–36.
Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–315.
Venkatesh, V., Morris, M. G., Davis, G., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly, 24*(3), 425–478.
*Wang, W.-T., & Wang, C.-C. (2009). An empirical study of instructor adoption of web-based learning systems. *Computers & Education, 53*, 761–774.
*Wang, Y.-S. (2003). Assessment of learner satisfaction with asynchronous electronic learning systems. *Information & Management, 41*, 75–86.
*Wang, Y.-S., Wang, H.-Y., & Shee, D. Y. (2007). Measuring e-learning systems success in an organizational context: Scale development and validation. *Computers in Human Behavior, 23*, 1792–1808.
Weller, M. (2007). *Virtual learning environments: Using, choosing and developing your vle*. New York: Routledge.
Wixom, B. H., & Todd, P. A. (2005). A theoretical integration of user satisfaction and technology acceptance. *Information Systems Research, 16*(1), 85–102.
*Wu, J.-H., Hsia, T.-L., Liao, Y.-W., & Tennyson, R. D. (2008). What determinates student learning satisfaction in a blended e-learning system environment?. In *Proceedings of the 12th Pacific Asia Conference on Information Systems* (pp. 1–14), Retrieved from. http://www.pacis-net.org/file/2008/PACIS2008_Camera-Ready_Paper_149.pdf [last accessed June 2011].
*Yeung, P., & Jordan, E. (2007). The continued usage of business e-learning courses in Hong Kong corporations. *Education and Information Technologies, 12*(3), 175–188.