A constructivist approach in a blended e-learning environment for statistics

Stephan Poelmans a,b & Patrick Wessa b

a Faculty of Economy & Management, Hogeschool-Universiteit Brussel, Belgium
b Leuven Institute of Research on Information Systems, KU Leuven, Belgium


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A constructivist approach in a blended e-learning environment for statistics

Stephan Poelmans\textsuperscript{a,b,}\textsuperscript{*} and Patrick Wessa\textsuperscript{b}

\textsuperscript{a}Faculty of Economy & Management, Hogeschool-Universiteit Brussel, Belgium; \textsuperscript{b}Leuven Institute of Research on Information Systems, KU Leuven, Belgium

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In this study, we report on the students’ evaluation of a self-constructed constructivist e-learning environment for statistics, the compendium platform (CP). The system was built to endorse deeper learning with the incorporation of statistical reproducibility and peer review practices. The deployment of the CP, with interactive workshops and group assignments, immerses students in a novel blended e-learning experience. Based on the Delone and McLean framework, we tested an explanatory success model with a sample of 607 business students, collected during three consecutive academic years. The results indicate that system quality and teacher support are the most important success factors, directly or indirectly contributing to a higher degree of relative advantage and satisfaction, both of which strongly determine continuous intention to use. The findings ascertain the usability and acceptance of the CP and promote a more radical constructivist approach to the teaching of statistics, but also other subjects.

Keywords: e-learning evaluation; statistics education; social constructivism; Delone and McLean

Introduction

E-learning environments are not just supposed to be a dedicated instrument to provide learners with learning materials and information but also to engage them and facilitate their learning process. The benefits of e-learning have been discussed in numerous studies (e.g. Bouhnik & Marcus, 2006; Liaw, 2008; Michael, 2006). Notwithstanding the increase in flexibility, the elimination of time and space barriers, and the possibility of collaborative learning, an e-learning approach may suffer from drawbacks. Typical risks include: a lack of peer contact and social interaction, substantial initial costs and efforts for preparing content materials, system maintenance and a need for appropriate tutorial support (Kinshuk & Yang, 2003; Wu, Tennyson, & Hsia, 2010; Wu, Tennyson, Hsia, & Liao, 2008).

Some of the above-mentioned concerns may be avoided by the provision of a blended learning environment that combines face-to-face classroom settings with instructional richness and self-paced e-learning (Akkoyunlu & Yilmazsoyulu, 2008; Wu et al., 2010).

Although blended e-learning can be a promising alternative, insufficient learning satisfaction might still be an obstacle for a successful blended e-learning system (BELS) implementation (Smyth, Houghton, Cooney, & Casey, 2011; So & Brush, 2008).

\textsuperscript{*}Corresponding author. Email: stephan.poelmans@gmail.com

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A review of previous research in learning technology shows that there is a lack of studies that have examined the crucial factors that determine learning satisfaction with BELS in particular (Smyth et al., 2011; Tselios, Daskalakis, & Papadopoulou, 2011).

An issue that may be underrated in the evaluation of an e-learning context is the pedagogical model that is implicitly or explicitly underlying the system. An e-learning system should not be considered as being pedagogically neutral (Wessa, De Rycker, & Holliday, 2011; Wu, Hiltz, & Bieber, 2010). We can, for instance, distinguish between a more conventional, objective approach, with a focus on transferring knowledge to students, and a more active, constructivist approach, supporting the learner to construct his own understanding in his interactions with peers and tutors (Fouser, 2010; Wu et al., 2010).

In this article, we study the assessment of a self-constructed, constructivist-oriented e-learning application (henceforth the compendium platform (CP)) that supports reproducibility of, and peer collaboration on statistical analyses. We deployed the CP in several statistical courses in undergraduate business programmes. The system was developed because we experienced the phenomenon of mere rote learning using a traditional e-learning environment to distribute course material, and providing conventional classes with exercises. Students typically studied in a superficial way, enough to pass the exam but without real understanding.

While the system is supposed to shift the locus of control to the student, its use has been accompanied by a mediating role of the instructor as well as peer students.

The aim of this study is to analyse the students’ evaluation of the CP and the way it has been used so far. Using the Delone and McLean’s (D&M) success model as a starting point increases our understanding of several success factors of the CP. The use of such an evaluation model also enables us to validate the feasibility and usefulness of integrating educational theories and e-learning systems’ design to provide engaging, blended e-learning environments in statistics as well as other fields that incorporate exercises and statistical computing.

In the next section, we present the CP and the way it has been deployed. Next, we provide a concise overview of the literature on e-learning success and we present our research model and hypotheses. In the fourth section we explore our sample and describe the reliability of the measurement model. After the presentation of the findings, we finish the paper with a discussion and general conclusions.

The CP

Pedagogical background

Choosing an e-learning platform cannot really be established independently from an underlying pedagogical model (Wu et al., 2010). Pedagogical theory presents two general learning perspectives: a more instruction-centred, objectivist approach versus a constructivist or active, student-oriented perspective (Michael, 2006; Vygotsky, 1978; Wu et al., 2010).

In the setting with an objectivist focus, knowledge is typically transferred by presenting lectures and responding to questions. In this model, each student is actually more stimulated to perform so-called “rote” or “surface learning,” i.e. mainly memorizing pure knowledge that is presented by the instructor (Wu et al., 2010).

In the constructivist way of teaching, students are active participants by applying concepts to problems, reflecting on proposed ideas, and creating appropriate insights based on peers and the instructor. The social constructivist paradigm regards learning as a typically social activity in which learners cooperate to build ideas that are formed and further shaped and appropriated through reactions and feedback of others (Fouser, 2010).
The constructivist paradigm induces “deep learning”, critical thinking, and a problem-solving behaviour (Muir-Herzig, 2004; Wu et al., 2010).

It has been reported that such a more active approach is effective and even more so than traditional passive ways of teaching (Cherney, 2008; Michael, 2006; Williams & Chin, 2009). This type of learning also best resembles the needs of a professional who is confronted with unpredictable and changing professional circumstances.

However, one pedagogical approach does not exclude the other and the same e-learning system can be used both ways: merely as a tool to distribute course material and/or as a tool that supports interaction, experimentation and knowledge construction. Even if an e-learning system is used in both ways, there is still an important relationship between the technological design of the system and the efficiency of the learning process (Wessa et al., 2011).

Our ultimate goal is to create a situation where students can learn and understand statistical methods at a deep level, as opposed to the rote memorization practices that we observed in the past. In our experience, it is possible to achieve fairly good results by using non-technological techniques such as direct instructor–student interaction, individualized instructor feedback, etc. (Wessa et al., 2011). However, due to external, temporal, physical and monetary constraints, it is not feasible to employ such teaching approaches in undergraduate statistics education with large student populations. In order to compensate for some of these constraints, we soon started to search for an innovative, technological solution.

The design of the CP

To build the system under scrutiny, the open-source software Moodle was used as the learning environment (Moodle, 2012). Its interactive and assessment features were substantially enhanced through the seamless integration of the CP as is outlined below.

To provide integrated statistical tools, the R framework is appropriate. R is an open-source programming language widely deployed by statisticians to perform statistical analyses and also to develop tailor-made statistical programs. The integration of the R framework into the CP allows students and educators to create documents that contain statistical computations that can be reproduced by any reader through a web browser. The reader clicks the hyperlink of the computation and receives all the information, allowing him to inspect every detail of the computation (including the computer algorithm, the data, parameters, etc.) and to re-compute or re-design the computations (by changing the parameters, the algorithms, or the datasets). In sum, all calculations are performed within the R framework, and contained in a reproducible document (compendium). The compendia are stored in the repository of the CP (see Wessa et al., 2011 for more details). Creating, and reproducing computations contained in a reproducible document does not require any technical skills.

The CP has equally been endowed with a self-constructed peer review (PR) component, enabling students to provide feedback, communicate solutions, and provide encouragements to fellow students. The PR technology that we developed is unique because it can be seamlessly integrated into other software (Wessa et al., 2011).

The deployment of the CP

The core section of the statistical courses in which the CP was deployed involves various workshops, replacing conventional lectures. The workshops have been designed so that the presented statistical problems cannot be solved without additional information, provided by the tutor. Because of this approach, it is clear that the use of the CP should be considered as a blended e-learning environment.
The courses that were offered contained a wide variety of statistical techniques and methods. The following topics were covered: probability, descriptive statistics, explorative data analysis, hypothesis testing, multiple linear regression, and time-series analysis. A total of 73 different types of techniques with a variety of model parameters were provided. For each technique, students had one or several web-based software modules available (based on the R language).

The provision of reproducibility and in particular peer-to-peer feedback meets the call of many constructivists for a richer virtual learning environment (VLE) (Liaw, 2008; Zhang, Zhou, Briggs, & Nunamaker, 2006). In the literature, the use of PR is considered as an important strategy in the design of instructional settings, including e-learning (Kollar, Fischer, 2010; Strijbos & Sluijsmans, 2009). Notwithstanding our treatment of peer rates as creative activities in which the peer grades do not count as a student’s final score, students received a strong incentive to perform well, using the PR component of the CP that keeps track of students’ PR activities.

In the beginning of the courses, a typical behavioural pattern consisted of confusion and many questions. For most students, their somewhat puzzled state of mind changed and improved during the course. In order to have an understanding of the factors that determine the success of the CP, as seen from the angle of the students, we developed a success model that we validated empirically in a period of three successive academic years. The model is inspired by the D&M success model and is explained in the following section.

**Success of the CP: research model**

**E-learning acceptance and success**

The D&M information success model (ISSM) is a prevalent dimensional model measuring the “success” of an operational information system (see Petter & McLean, 2009 for a meta-analysis). Success is a multi-dimensional concept, containing constructs such as information and system quality, satisfaction, intention (or use), and net benefits. A strength of the ISSM is its orientation towards the design quality of the hard- and software, the service supporting its deployment, and the information that is provided by it; making it useful to foster practical ramifications such as design guidelines (Wixom & Todd, 2005). There is a plethora of research related to the ISSM; in the field of e-learning, the number of studies inspired by the D&M model is still relatively limited (for instance, Eom & Stapleton, 2011; Holsapple & Lee-Post, 2006; Lin, 2007; Wang, Wang, & Shee, 2007).

In the following, we present our hypotheses, inspired by the D&M framework, but adding some constructs that are particularly relevant for the CP, such as its reproducibility feature and the importance of PR and teacher support.

**Research hypotheses**

**Intention to use, relative advantage and satisfaction**

In recent models of IS success, net benefits, use intention and user satisfaction are proposed as key success measures. User satisfaction has been defined as the global feelings and attitudes that stem from aggregating all the efforts and benefits that an end-user receives from using an information system (Ives, Olson, & Baroudi, 1983; Wixom & Todd, 2005). As such, user satisfaction is closely associated with system benefits (Wu & Wu, 2005). In the literature, perceptions have been proposed to proxy net benefits, because of the difficulties in measuring net benefits in an objective way. A typical example is perceived usefulness
(Wu & Wu, 2005), which has frequently been modelled as a determinant of satisfaction (Landrum, Prybutok, Strutton, & Zang, 2008; Rai, Lang, & Welker, 2002).

In our approach, students have no alternative to earn their credits but to use the CP. Therefore, we argue that the usefulness of the system for students is to some degree apparent anyhow. Since all students have received statistical courses previously, it is more credible to ask students to compare the use of the CP with the conventional teaching methods they are acquainted with. In line with the literature on the diffusion of IS (Rogers, 2003), we call these perceived relative benefits, relative advantages.

Thus, we propose:

\( H1: \) Relative advantage positively influences satisfaction.

Intention to use is defined as the intention of the end-users to use the system in the future. In the ISSM, it is hypothesized that individuals’ intentions to use information systems are dependent on their evaluation of its usefulness. An e-learning system that supports the student in gaining a deeper understanding of the course’s objectives, and that is perceived better than other teaching methods, will likely stimulate the students to use such a system in the future (if available). We therefore propose:

\( H2: \) Relative advantage positively influences intention to use.

While relative advantage is to be conceived as a true instrumental measure, more general feelings about using the system, as aggregated in the concept of satisfaction, will also likely influence the likelihood of its future use. The impact of satisfaction on intention is also confirmed in the meta-analysis of D&M (Petter & McLean, 2009). Thus, we hypothesize:

\( H3: \) Satisfaction positively influences intention to use.

Information quality
DeLone and McLean (2003) define information quality as a multi-dimensional concept that relates to the accuracy, timeliness, completeness, relevance and consistency of the information that is provided by the system. Ample evidence exists to endorse the causal relationships between information quality and usefulness (Petter & McLean, 2009). It is plausible that if the information provided by an e-learning system is meeting the requirements of the students, it is likely that the relative advantage will increase. We thus state:

\( H4a: \) Information quality has a positive impact on relative advantage.

In a similar reasoning, we can expect information quality to increase satisfaction perceptions as well. Better information will help to accomplish tasks, thus increasing satisfaction in how the system supported the work. A lot of evidence exists to show that this proposition holds empirically (e.g. Doll & Torkzadeh, 1988; Seddon & Yip, 1992). Consequently, we have:

\( H4b: \) Information quality has a positive impact on satisfaction.

System quality: general attributes and reproducibility
System quality is a multi-dimensional concept, which pertains to the qualities of the hard-
and software that is used to produce or disseminate information. D&M propose several
system quality dimensions, including the reliability of the system, its functionalities, the integration with other systems, the responsiveness to user interactions, and general perceptions of ease of use (Delone et al., 2003).

System quality has been measured in different ways, as an aggregation of a varied number of sub-dimensions (e.g. Landrum et al., 2008; Rai et al., 2002; Wixom & Todd, 2005; Wu & Wang, 2006). Typical dimensions such as reliability, responsiveness and ease of interaction are relevant, not only to the CP but to most information systems, describing key traits that are actionable through appropriate system design interventions. Likewise, because the CP is web-based, navigation is such an actionable characteristic, determining the ease with which learners can navigate between web pages. Consequently, we consider reliability, ease of interaction, responsiveness and navigation as general system quality attributes constituting general system quality.

The general quality perceptions of an information system will enable users to reap performance benefits more easily (Nelson, Todd, & Wixom, 2005). Such a situation likely increases the satisfaction about the use of the system. Thus, we propose:

\[ H5a: \text{General system quality has a positive impact on relative advantage.} \]
\[ H5b: \text{General system quality has a positive impact on satisfaction.} \]

A key trait that makes our e-learning component unique however is its capacity to support the reproducibility of statistical computations. Reproducibility should be conceived as an idiosyncratic, constructivist characteristic, enabling students to re-calculate their own exercises, as well as those of their peers. Consequently, it increases the added value of the CP and a student’s evaluation of this functionality will probably determine the evaluation of the CP’s relative advantage and associated satisfaction.

Based on the arguments above, we propose:

\[ H6a: \text{Reproducibility has a positive impact on relative advantage.} \]
\[ H6b: \text{Reproducibility has a positive impact on satisfaction.} \]

Teacher support as a proxy of service quality

In their revision of the ISSM, Delone and Mclean (2003) included service quality in their model, defined as the quality of the services and support provided by the IT staff. Within the specific context of e-learning, the importance of students’ interactions with their instructors has been emphasized as determining the course satisfaction level and learning performance (Paechter, Maier, & Macher, 2010; Yukselturk & Yildirim, 2008).

In our statistical classes, hands-on training and instructions are provided throughout the weekly workshops. The students rely on the instructor to guide them, technically as well as with respect to the contents and the assignments. In this way, the student–teacher interaction, what we call teacher support, is to be seen as service quality. We argue that the more a student is supported during her operations, the more she will use it to its full potential. This will likely result in a higher relative advantage score but also a higher degree of satisfaction. We thus hypothesize:

\[ H7a: \text{Teacher support has a positive impact on relative advantage} \]
\[ H7b: \text{Teacher support has a positive impact on satisfaction.} \]

In our rationale, we distinguish between a better knowledge of the application, and the contents of the system (including the assignments and the course material required to complete
the assignment). Therefore, it is plausible to presume that the impact of teacher support on relative advantage might be mediated by its impact on both system quality and information quality. Although the impact of service quality on information and system quality is not conceived in the D&M model, we propose tentatively:

- **H8a**: Teacher support has a positive impact on information quality.
- **H8b**: Teacher support has a positive impact on general system quality.
- **H8c**: Teacher support has a positive impact on reproducibility.

**Peer review**
Useful interactions need not be confined to teacher–student communication. Johnston, Killion, and Oomen (2005) argue that when learners believe that blended e-learning environments provide effective student-to-student and student-to-teacher interactions, this will improve the learning climate and increase the satisfaction with the e-learning system. Paechter et al. (2010) showed that the feeling of group cohesion has an effect on students’ engagement in team work in a learning environment, and course satisfaction. Wu et al. (2010) also argue that the interactions among students, as well as those between the educational institution and the students are crucial to the learning process and influential to the beliefs about an e-learning environment.

Accordingly, similar to the role that we assigned to the teacher, peers can also support each other in their quest to understand the course material and the assignments. Hence, it is plausible to presume that PR, being an integral part of the CP, will contribute to an increase in the perceived relative advantage of the CP. As the comments of peers are distributed through the CP and stored in it, they will probably augment the perceived information quality of the compendium.

As a result, we propose:

- **H9a**: Peer review has a positive impact on relative advantage.
- **H9b**: Peer review has a positive impact on information quality.

Summarizing the above hypotheses, we built the research model of Figure 1.

**Validating the research model**

**Measuring the concepts**
Most of the items used were gathered from established questionnaires and constructs such as the computer system usability questionnaire (CSUQ; Lewis, 1995), and the Constructivist On-Line Learning Environment Survey (Taylor & Maor, 2000). Some items were adapted cautiously to reflect our particular context and we also added items in harmony with our research model. Below we present the reliability and validity of the measurement model.

The constructs were measured as latent variables, using reflective items (except for general system quality). The reflective items (questions) of one variable should have a high degree of interdependency as they measure the same underlying phenomenon.

General system quality is treated differently. It is considered as a second-order factor, composed of 12 formative items that represent distinctive underlying sub-dimensions such as: ease of use, responsiveness, reliability, interaction, navigation and functionality (see also the CSUQ). The 12 items are formative because they do not need to be interdependent and they can contribute differently to general system quality. As an example, a
student may perceive the CP as generally easy to use (indicated by a high score on items SQ1 and SQ3 of Appendix 1), but nonetheless find it rather slow (resulting in a lower score on item SQ9), or still observe that certain functionalities are missing (see item SQ7).

Reproducibility as a newly developed concept was measured using five reflective items, asking about the added value of the reproducibility functionality in the learning and collaboration process.

Administration of the surveys
In the course of three successive academic years between 2008 and 2011, at the end of a semester, paper-based questionnaires were given to 776 students in total. Our sample consists of 607 students—a response rate of 78%—with an average age of 21 years. They either possessed a professional bachelor’s degree or they were in the final year of their academic bachelor (in business economics). All students had received one or more basic statistical courses previously.

Measurement reliability of the latent variables
As a first step, the obtained multi-item constructs were tested for validity and reliability. Reliability includes the estimation of internal consistency of the reflective items of a latent construct. To certify that the constructs measure what they are supposed to, convergent and discriminant validity tests were performed to investigate whether constructs are intercorrelated in an expected way. Reliability and validity were assessed with factor analysis and the computation of Cronbach’s alpha, the composite reliability and the average variance extracted (AVE), for each construct. Table 1 shows the results.

All constructs show sufficient internal consistency with appropriate Cronbach’s alpha of at least 0.73 (but mostly higher than 0.8) (Nunnally & Bernstein, 1994). Table 1 also demonstrates that the composite reliability and AVE for each construct are above the expected thresholds of, respectively, 0.7 and 0.5 for all latent constructs, suggesting adequate convergent validity (Hair, Black, Babin, Anderson, & Tatham, 2006). Discriminant validity is achieved (i) when the items load much higher on their own latent variable
than on other variables, and (ii) when the square root of each construct’s AVE is larger than its correlations with other constructs (Chin, 1998). While we omit the display of all item cross-loadings in the interest of brevity, we confirm that all items loaded on their constructs as expected. Finally, the data were tested for multi-collinearity in case of more than one predictor construct. In all cases, the variance inflation factor was below the 5.0 threshold, meaning that the relationships among multiple predictors are not distorting the explanatory model.

Findings

Data inspection

In an initial step, we examined descriptive statistics about the CP evaluation (Table 2). With the items being measured on five-point Likert scales, average scores above 3 can be considered as positive beliefs. Overall, 69% of the end-users are satisfied with the CP and 62% find it beneficial (with average scores of 3.54 and 3.50, respectively). Sixty-seven per cent claim that they would use such a system in the future (intention). In general, end-users were satisfied with the teacher support and PR they had received, with average scores of 3.80 and 3.61. Splitting the sample according to gender resulted in two cohorts with comparable means and variances on all constructs considered (both ANOVA and F-tests were applied), with only significantly higher female scores for PR.

Testing the hypotheses

To test for the hypotheses of the structural model of Figure 1, we used partial least squares (PLS) analysis with the program SmartPLS (Ringle, Wende, & Will, 2005). PLS is

<table>
<thead>
<tr>
<th>Construct</th>
<th>Composite reliability</th>
<th>Cronbach’s α</th>
<th>AVE</th>
<th>Items</th>
<th>Factor loading</th>
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<td>0.86</td>
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<td></td>
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<td>INT2</td>
<td>0.92</td>
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<td>Teacher support</td>
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<td>PR2</td>
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specifically appropriate for examining complex explanatory models with formative as well as reflective indicators (Diamantopoulos & Winklhofer, 2001).

In a first step, we used the complete data set to test the hypotheses of the model of Figure 1; estimating the path coefficients and the \( R^2 \) values. Whereas \( R^2 \) represents the percentage of the individual differences (variances) in the scores on a dependent variable that can be explained by the model, the path coefficients (beta coefficients) determine the effect size of the hypothesized path between two variables. A bigger beta coefficient (in absolute value) represents a stronger effect.

The results displayed in Figure 2 and Table 3 show that our global model \((n = 607)\) explains 52%, 75%, and 36% of the individual differences (variances) in the scores on, respectively, intention, satisfaction and relative advantage. The majority of our hypotheses are confirmed. As expected, relative advantage and satisfaction were significant predictors of intention \( (\beta_{\text{rel.A.}} = 0.30 \text{ and } \beta_{\text{sat.}} = 0.50) \); thus confirming \( H2 \) and \( H3 \). General system quality and information quality are the most important predictors of relative advantage and satisfaction, which support \( H4a, H4b, H5a \) and \( H5b \). Relative advantage

<table>
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<th>Table 2. Descriptive statistics.</th>
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<td>Intention</td>
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<td>Information quality</td>
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<td>General system quality</td>
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<td>Reproducibility</td>
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<td>Teacher support</td>
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<td>PR</td>
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<td>Age</td>
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*Significant gender difference.

Figure 2. Validated model.
is also considerably influenced by reproducibility and PR (in support of H9a and H6a). Information quality is significantly determined by PR and to a lesser extent by teacher support (with a smaller $\beta$) (endorsing H9b and H8a). Teacher support does not influence relative advantage and satisfaction directly (a rejection of H7a and H7b) but it has a crucial role because of its direct impacts on general system quality, reproducibility and information quality (with $\beta_{GSQ} = 0.31$, $\beta_{repro} = 0.32$, and $\beta_{IQ} = 0.17$; H8b, H8c and H8a are supported).

In a second step, we examined the model separately for the students of the three academic years and compared the path coefficient differences, employing the non-parametric multi-group comparison method of Henseler, Ringle, and Sinkovics (2009). Considerable fluctuations in path coefficients would point to a cohort-effect that moderates the
relationships of the model, making the model less generalizable. The results indicate a limited moderation effect of cohort 1, i.e. a significant difference in the importance of the impact of system quality on relative advantage, and in the importance of teacher support as a determinant of information and general system quality (Table 3). No significant differences exist between cohort 2 and cohort 3. Consequently, the established model should be considered as stable over time.

Discussion
While using a traditional e-learning environment, i.e. blackboard, to distribute course material and providing regular statistical classes, we noticed the mindless students’ way of rote learning to prepare for the exam. To counter this situation, we opted for the implementation of an e-learning system that embraces the social constructivist perspective.

Our approach was distinctive in the following ways:

- We offered students data sets on which they can (re)produce calculations from peers or themselves.
- We provided a lot of (electronic) documents, manuals and a variety of techniques from which they have to choose.
- The system enables students to submit review messages about the submitted compendia of their peers.

Our setting can be categorized as a major deviation of the mainstream higher education statistical courses. The fact that we present data from more than 600 students over three consecutive academic years, and the limited number of moderation effects (only 3 differences in 16 path coefficients between group 1 and the other two groups), confirms the stability of the relationships that we could establish. Despite the relatively new way of constructivist learning and the resistance that we encountered in the beginning of the courses, Table 2 depicts that the CP was accepted by students at the end of the courses.

The main model has a good explanatory capacity, explaining between 36% and 75% of individual differences in our success variables. It confirms the majority of our hypotheses. Teacher support has been attributed a considerable importance; not as a direct determinant of satisfaction or relative advantage ($H7a$ and $H7b$ are not supported), but as the most important antecedent of general system and information quality ($H8a$ and $H8b$) and reproducibility ($H8c$).

From a practical point of view, this role of teacher support implies that in order to understand and appreciate the system, its information and its reproducibility feature, students within the context of blended e-learning rely heavily on the guidance of the lecturer. In a context where students receive extra information and assignments in a weekly workshop where they can ask questions, this does not come as a surprise. The importance that students attribute to teacher support is also in harmony with the theoretical stance emphasizing the crucial role of stimulating interactions between students and teachers.

The role of teacher support as a crucial antecedent of system and information quality further implicates that in educational institutions and other organizations, which are in the process of selecting or implementing e-learning, the supporting role of e-learning systems should not just be left to an IT helpdesk, providing technical aid. What may easily be overlooked is the role of the lecturer who not only needs to use the tool, but also needs to support the learners in their endeavour to get a grasp on the system and its contents (information). The role of the lecturers is certainly important in an educational
institution where students are typically not trained to use the tool outside their curriculum. In a company or other organization, this approach will likely be different as employees, targeted to work with e-learning systems, might receive extra training before actually usage. In higher education, e-learning will certainly not take over the role of the lecturer.

Not only lecturers, but also peers have a crucial importance, as is manifested by the direct impact of PR on relative advantage (H9a) and information quality (H9b). The PR process is in the first place oriented towards the completion of the assignments. Accordingly, by reproducing others’ exercises and in order to give meaningful feedback, a proper understanding of the system and the ability to refer to the course material are indispensable (for instance, to explain mistakes and the use of alternatives or more appropriate techniques). Consequently, the process of PR also contributes to their perception of the usefulness of the CP and its contents (as witnessed by an increased perceived relative advantage and information quality). Although not tested in this paper, in other research, we have also shown that PR has an important role and that peer feedback increases the chances to perform well at the exam (Wessa et al., 2011). All these findings empirically validate the, often theoretical, assumption of a more constructivist approach, in which peer interactions are indispensable to create mutual knowledge, despite their lack of expert knowledge.

From a theoretical point of view, our study answers the call in the literature for more research on the drivers of learning satisfaction with BELSs in particular. Although a generalizable modification of the D&M model for e-learning purposes is not our first goal, our proposed success model has a noticeable characteristic that deserves further consideration: the role of teacher support (and also PR) as a direct determinant of system and/or information quality. In the D&M literature, system quality, information quality and service quality are typically seen as exogenous variables. To our knowledge, their inter-relationship has not been investigated yet. Nevertheless, it seems particularly plausible that service quality can be seen as a determinant of information and system quality (see the section above, “Teacher support as a proxy of service quality”). Given the particular context that we investigated, teacher support and PR are proposed as proxies for service quality. The confirmation of H8a, H8b and H9b confirms its impact on system and information quality. Although service quality may be differently organized in non-educational institutions or when considering other types of information systems, we do not see a reason why this relationship between service and system and information quality within the ISSM should not be further considered in future research.

Conclusions
Educational technology cannot be designed in a pedagogical neutral way. In this article, we present the evaluations of a self-constructed e-learning environment, designed to stimulate a deeper learning process. The CP has, as unique properties, a feature to perform statistical reproducibility and a re-usable PR component. The use of the CP, with interactive workshops, group assignments and an emphasis on PR, radically deviates from traditional statistical courses and immerses students in a social constructivist blended e-learning environment.

Using a sample of 607 higher education business students, from three successive academic years, we verified a D&M-based success model.

The originality of the model is to include factors such as reproducibility, PR quality. Also the position of teacher support as a determinant of system and information quality has not been investigated in a D&M model yet.

The students’ evaluations clearly endorse the feasibility of a profound constructivist technology design. Students indicated the particular importance of general system quality
but also the role of teacher support, which cannot be substituted by a system’s design quality. The quality of the information in the system, reproducibility and the PR process are also confirmed as significant determinants of relative advantage and satisfaction. Our future research will consider objective measures such as PR messages and exam scores, and it will also focus on discourse analyses of PR messages.

Notes on contributors
Stephan Poelmans, PhD, is an Associate Professor in Business Information Management at the Hogeschool-Universiteit Brussel. He is also an affiliated researcher at the Leuven Institute for Research on Information Systems of the faculty of Business and Economics in the Katholieke Universiteit Leuven (KU Leuven), Belgium. His main areas of research include: the evaluation of the design and the usability of information systems (with a focus on e-learning and enterprise information systems), and service-based software development.

Patrick Wessa, PhD, studied Quantitative Economics in Belgium and obtained his PhD at the Institute for Econometrics and Statistics (University of Basel, CH). He leads the Reproducible Computing project and is primarily interested in multidisciplinary research that focuses on the intersection between information technology, statistics and education. In past years, he designed several innovative technologies and web applications for private companies, universities and the European Commission.

References


Interactive Learning Environments


Appendix 1. Survey items

General system quality

- SQ1: It was simple to use the CP
- SQ2: I feel comfortable using the CP
- SQ3: It was easy to learn to use the CP
- SQ4: Whenever I make a mistake using the CP, I recover easily and quickly
- SQ5: The information (such as online help, on-page messages and other documentation) provided with this website is clear
- SQ6: It is easy to find the information I need
- SQ7: The CP has all the functions and capabilities I expect it to have
- SQ8: The CP contains sufficient hyperlinks to navigate
- SQ9: Overall I found that the CP was able to quickly perform statistical computations
- SQ10: It is easy to move from one page to another
- SQ11: Overall the website reacts quickly and I do not have to wait too long to go to a new page or to download information
- SQ12: The software is stable and does not crash regularly
Reproducibility

- RE1: The fact that I can reproduce computations of others is beneficial for my learning
- RE2: Papers that make use of reproducible computations are easier to assess
- RE3: Reproducible computing helps me to communicate about statistics
- RE4: Reproducible computing helps me to collaborate with other students
- RE5: My learning improves because the website allows me to reproduce and reuse the computations of others

Information quality

- IQ1: The information provided by the CP is easy to understand
- IQ2: The information is effective in helping me complete the tasks and scenarios
- IQ3: The organization of information on the website pages is clear
- IQ4: The content of the CP meets my expectations

Teacher support

- TS1: The tutor stimulates my thinking
- TS2: The tutor encourages me to participate
- TS3: The tutor models good discourse
- TS4: The tutor models critical self-reflection

Peer review

- PR1: Sending feedback messages to other students encourages me to explore and learn
- PR2: Receiving feedback messages from other students encourages me to explore and learn

Relative advantage

- RA1: Learning Statistics with the CP is more effective than with a traditional handbook
- RA2: To learn statistics the CP is better than the statistical courses I have had so far

Satisfaction

- Sat1: Overall I am satisfied with how easy it is to use this system
- Sat2: Overall I am satisfied with the CP
- Sat3: I would recommend this website to friends

Intention

- INT1: I intend to use the CP when I need to apply statistics in the future
- INT2: Next year, I will probably use the website/software again if I have to do statistical assignments