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Open-source learning management systems: a predictive model for higher education

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Abstract The present study investigated the role of pedagogical, technical, and institutional profile factors in an institution of higher education's decision to select an open-source learning management system (LMS). Drawing on the results of previous research that measured patterns of deployment of open-source software (OSS) in US higher education and the relative importance of specific selection criteria when considering an OSS LMS, a Web survey was conducted among 285 Chief Information Officers and Chief Academic Officers from a variety of US institutions to determine patterns of OSS LMS deployment, as well as the influence of specific selection criteria. Binary logistic regression analysis revealed Carnegie Classification, institutional governance, previous experience with OSS, focus on student learning, and the commitment to organizational self-reliance to be key influencers in the OSS LMS selection decision. The implications of these findings for future research and for institutional decision-making are discussed.

Keywords higher education, learning management systems, open source, predictive modelling.

Introduction

Open-source software (OSS) – software free of license fees and delivered with its computer program source code according to the criteria established by the Open-source Initiative [Open Source Initiative (OSI), n.d.] – has been touted as a means of addressing the rising costs of campus-wide software applications, while enabling the creation of learner-centred systems. Arguments favouring OSS have been well documented in the literature. Common themes cited by proponents include OSS as: (a) an example of technology for the common good (Coleman 2004); (b) a new software development paradigm with security and risk-management benefits (Raymond 2001); and (c) a means of eliminating vendor license fees (Williams van Rooij 2009).

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In higher education, the discussion about OSS for teaching and learning has centred around course management/learning management systems (CMS/LMS). What began in the 1990s as stand-alone Web-based course management systems, intended as administrative support for classroom instruction, have since evolved into enterprise-wide LMS that also include social software tools such as blogs and wikis, as well as interfaces to an institution's student information and financial administrative systems. The leading OSS LMS products are Moodle (http://www.moodle.org), originally developed in Australia, but currently with a global user base that includes nearly 30 000 registered sites, one million courses, and available to anyone for downloading, and Sakai (http://www.sakaiproject.org), a platform developed by a group of US and international institutions that includes generic collaboration tools, along with teaching and portfolio tools available under an Education Community License. Other OSS LMS products include Claroline (http://www.claroline.net), available in more than 35 languages and used in 80 countries; .LRN (http://www.dotlrn.com), a system that has e-commerce and project management applications built in; ATutor (http://www.atutor.ca), developed in Canada and includes more than 17 000 registered user sites, and; Bodington (http://www.bodington.org), developed in the U.K. and implemented at the University of Leeds and the University of Oxford. The Western Cooperative for Educational Telecommunications provides reviews and product comparisons to assist decision-makers in selecting the LMS – commercial or OSS – that meets their institution's e-learning needs (EduTools 2010).

LMS have become mission-critical to higher education and as essential to ongoing operations as student information systems, financial systems, human resource systems, and e-mail systems. Nearly all (97.5%) institutions of higher education in the United States have deployed at least one LMS campus-wide (Green 2009), enabling them to maximize the use of technology investments to support multiple instructional models. Open-source LMS have gained attention due largely to the decline in the number of commercial vendors over the past 10 years. Further, higher education's experiences with commercial LMS have been mixed. On the one hand, the default design of these systems has been criticized for limiting instructional creativity by forcing instructors who are novice users of these systems into the traditional lecture-based model of instruction, and also for lacking good value-added development resources to supplement the limited instructional design skills of the average faculty member (Carmean & Haefner 2003; Papastergiou 2006; Lane 2008; Sclater 2008). On the other hand, studies of individual courses using commercial LMS have found that those technologies enhanced the learning experience by enabling collaboration, the development of a sense of community, and the inclusion of constructivist strategies of collaborative learning into the instructional environment (Iyer 2003; DeNuei & Dodge 2006; Gill 2006).

Much of the research related to open-source LMS focus on post-acquisition adoption and implementation (Cornelius 2006; Chao 2008; Canas 2009; Caudill 2009; Green 2009). Feature/function comparisons with commercial LMS (Sclater 2008; EduTools 2010), as well as user case studies focusing on faculty and student experiences (Beatty & Ulasewicz 2006; Cavus *et al.* 2008; Martin-Blas & Serrano-Fernandez 2009), have also been well documented. These themes of adoption, implementation, and functionality vs. commerical products, are consistent with the directions and trends in research on OSS infrastructure applications, such as Apache for web servers, the Linux operating system, and the Mozilla Firefox web browser. However, the agglomeration of factors that influence an institution's decision to select an open-source LMS, particularly factors related to student learning, has not received such in-depth examination. This paper reports the results of a study to construct and validate a model of the key drivers contributing to a go/no-go decision for open-source LMS selection. The paper begins with a brief review and critique of current LMS evaluation models, then proposes an alternative perspective. This paper does not take sides in the OSS vs. commercial LMS debate. Instead, the paper offers research insights into the predictors of OSS LMS selection and the extent to which pedagogical considerations play a role in that selection.

Current LMS evaluation models

Current LMS evaluation models can trace their origins to a large body of research on evaluation criteria for enterprise-wide software systems. In a study of the relative importance of evaluation criteria for enterprise systems, Keil and Tiwana (2006) reviewed scholarly and practitioner articles on software selection criteria published from 1980 to 2001 and identified seven salient attributes of software that the literature reports as essential: cost, reliability, functionality, ease of use, ease of customization, ease of implementation, and vendor reputation. These seven attributes have informed the development of Likert scale-graded checklists used in public sector organizations (US Office of Personnel Management, n.d.) and promoted as best practices by professional associations focused on education and training (The eLearning Guild 2010).

In a comparison of papers published in the information technology literature between 1998 and 2006, Kljun *et al.* (2007) focused on LMS features and divided them into seven groupings that combine the feature/function criteria with usability and ongoing support criteria. Evaluation models for LMS intended to serve as e-learning platforms tend to refine the usability criteria to increase the emphasis on learner focus. For example, Kim and Lee's (2008) model used the results of a survey of 163 e-learning scholars and practitioners to generate their seven-factor LMS evaluation model that includes suitability of design in screen and system, interoperability of system and suitability of academy administration, easiness of instruction management and appropriateness of multimedia use, flexibility of interaction and test and learner control, variety of communication and test types, and user accessibility.

Drawing on studies of critical success factors (CSFs) – methods that enable Chief Executive Officers to recognize their own information needs so that information systems can be built to meet those needs (Rockart 1979) – Salmeron (2009) queried a panel of experts at higher education institutions to identify 10 CSFs for LMS that combine functionality, usability, and attitudinal measures. The relationship between the CSFs was then modelled using fuzzy cognitive maps, so that higher education decision-makers could make prediction comparisons between numerous tools measured by multiple factors and their relations.

Another approach to LMS evaluation focuses on the evaluation of LMS as a complex decision-making problem. Using a multi-attribute decision support model that consisted of non-numerical qualitative criteria (e.g. 'target user group', 'ease of use') ordered hierarchically into a tree structure, Arh and Blazic (2007) compared Blackboard, CLIX, and Moodle, and concluded that CLIX was the most suitable for the chosen target group of users in the study, namely, employees in small and middle-sized companies. This is consistent with the fact that CLIX was originally designed for corporate e-learning settings, whereas Blackboard and Moodle were originally designed for educational settings. Other studies have supplemented decision support models with models that prioritize user functional and technical requirements (Abdelhakim & Shirmohammadi 2008; Terawaki 2009). Still others view LMS as standardized products with similar generic tools such as quizzes/tests and communication and collaboration spaces, and emphasize implementation success case studies from peer organizations as the primary decision-making drivers (Black *et al*. 2007).

Common to all of these models is the focus on the attributes of the LMS and what decision-makers deem to be the relative importance of those attributes. Missing from these traditional evaluation models is the role of context, the situational factors in which learning takes place, and which need to be identified and accommodated to inspire learning and knowledge transfer (Tessmer & Richey 1997). The importance of context in decision-making has been recognized in a variety of fields including finance (Clark & Strauss 2008), national security (Eaneff 2008), and behavioural psychology (Beale 2007). In higher education, situational factors include the collaborative decision-making process (e.g. *ad hoc* committees that include administrative, faculty and student representatives, and the relative influence of process partcipants), as well as institutional characteristics such as Carnegie Classification and institutional. The context in which LMS decisions are made is as critical to understanding the decision choice set – vendor vs. open-source, vendor vs. vendor – as are the attributes of the LMS in the choice set.

An alternative approach

In a previous study to determine the extent to which US institutions of higher education are considering OSS for campus-wide efficiencies and for constructing an integrated learning environment that serves both the academic and the business sides of the institution (Williams van Rooij 2007a), the researcher constructed a list of pedagogical and technical factors that contributed to the decision to select OSS for teaching and learning. Study results indicated a singular focus on the pedagogical factors among academic respondents versus the technical efficiencies focus among technical and administrative respondents. Results also indicated a possible relationship between OSS selection and Carnegie Classification.

In 2009, a second implementation of that study sought to identify changes in the OSS landscape versus 2006 (Williams van Rooij 2011b). It also offered an opportunity to explore the extent to which the pedagogical and technical factors identified in 2006 can predict whether or not an institution will select an OSS LMS and what the characteristics are of institutions who opt in for OSS versus those who opt out. This paper reports the results of an analysis of a subset of the data from the 2009 study. Specifically, the purpose of the present research is to construct a model for evaluating an OSS LMS by (a) identifying the pedagogical, technical, and institutional profile factors that contribute to the decision to select (or not select) an open-source LMS campus-wide, and (b) determining the relative impact of these factors in predicting the likelihood of a go/no-go decision on an open-source LMS.

Method

Design and sampling frame

A Web-based survey was conducted among US higher education administrators responsible for the acquisition and deployment of administrative and academic software systems. Respondents included the Chief Technology Officer or Chief Information Officer (CTO/CIO), who is responsible for the information technology infrastructure of the institution, and the Chief Academic Officer (CAO), responsible for the institution's instruction and research affairs.

To obtain results reflective of the total population of regionally and/or nationally accredited institutions, a list of CAO and CIO names and e-mail addresses drawn via stratified random sampling of the various Carnegie classifications was purchased from Higher Education Publications, Inc. (HEP), publisher of the Higher Education Directory (Higher Education Publications 2009). To supplement the pool of potential respondents, a call for participation was also posted on the website of EDUCAUSE, one of the largest and most well-known associations dedicated to using technology in higher education.

Survey instrument and measures

As in the previous study, the current survey traced patterns of deployment, the relative influence of specific selection criteria, and specific metrics and processes used in selection decision-making, using a combination of closed-ended and open-ended questions. The same 16-item selection criteria scale used in 2006 was also used in the 2009 administration of the survey. The selection criteria scale was designed to indicate the extent to which respondents deem each of the item-attributes as influencing their consideration of an OSS LMS. All respondents were presented with a list of 16 pedagogical, technical, feature/function, and business attributes, and were asked to rate the extent to which each attribute influenced their consideration of OSS LMS using a 5-point scale, where '1' means 'strong positive influence' and '5' means 'strong negative influence'. Respondents were also given the option of indicating that an attribute was not a factor in their consideration of OSS LMS. This differs from the process used in the 2006 survey administration, where the pedagogical attributes were asked only of CAO respondents and the technical, feature/function, and business attributes were asked only of CIO respondents.

The reason for the change in 2009 was the increasing awareness of OSS as a means of achieving campus-wide efficiencies (Green 2009). Specifically, the researcher hypothesized that CAOs and CIOs have become more aware of the need to evaluate all campus systems in terms of their impact on teaching, learning, and research and as such, would be less likely in 2009 to respond 'don't know' to the attributes that were outside their areas of direct responsibility. A crosstab of 2009 attribute ratings by respondent function title showed no difference between CAOs and CIOs in the percentage of 'don't know' responses to any of the attributes, confirming that hypothesis. The 16-item list of selection criteria was subjected to an item reliability analysis via Cronbach's α, to measure the extent to which the items are related to each other and to obtain an overall index of the internal consistency of the scale (Creswell 2002). The Cronbach's α coefficient was 0.934, considerably higher than the social sciences norm of 0.700.

Procedure

Target respondents were sent a hyperlink to the URL address of a secured third-party server hosting the survey. Data were collected in the summer of 2009, and the total number of completed surveys was 285.

As shown in Table 1, the 2009 sample demographics are nearly identical to those of 2006. The over-representation of doctoral/research institutions in 2009 is also consistent with 2006, reflecting the first-mover role that doctoral/research institutions have traditionally assumed in US OSS higher education projects, such as Sakai, a platform for teaching, learning, and research (Sakai, n.d.) and Kuali, an administrative software system exclusively for higher education (Kuali Foundation 2010).

Statistical analyses

Principal component factor analysis with Varimax rotation was performed on the 16-item list of OSS LMS selection criteria using SPSS statistical software (version

Table 1. Respondent demographics, 2006 vs. 2009.

	2006 ($N = 772$)	2009 ($N = 285$)	% total HEP population (2009)
Carnegie Classification			
Associates	24.5%	28.9%	40.5%
Baccalaureate and baccalaureate/associates	23.1%	19.8%	18.2%
Masters	23.8%	24.7%	15.7%
Doctoral/research	23.1%	23.6%	7.0%
Specialized institutions	4.7%	3.0%	17.8%
Other/unclassified	0.8%	0.0%	0.5%
Governance (2008 Digest of Education Statistics)			
Public	54.3%	50.2%	38.7%
Private, nonprofit	42.3%	44.9%	37.3%
Private, for-profit	3.4%	4.9%	24.0%

HEP, Higher Education Publications, Inc.

18.0). This method was selected in order to reduce the original list to a more manageable number of predictors, while maintaining factor independence and interpretability (Gorusch 1983). Factor loadings greater than 0.600 were used in the interpretation of rotated factors. Item nonresponse led to some missing information. However, a missing values analysis revealed that 210 (74%) respondents rated all 16 items, while the remaining 75 respondents (25%) rated none of the 16 items. Although there is no fixed rule about the treatment of missing data, the general social sciences practice in multivariate analyses of small to medium-size samples with a large number of missing values is to drop those cases rather than do data imputation and replace those missing values (Schafer 1997; Allison 2001). Consequently, the factor analysis was run using only those cases rating all 16 items.

Principal component factor analysis of the 16-item list of OSS LMS selection criteria yielded four factors that together accounted for 75% of the variance. Factor 1, labelled Student Learning, included all of the pedagogical attribute items and accounted for 28% of the variance (eigenvalue = 4.16). Factor 2, labelled System Support, included the attribute items focused on system maintenance and sustainability, and accounted for 18% of the variance (eigenvalue = 2.74). Factor 3, labelled, System Stakeholders, included the attribute items centred around organizational personnel and accounted for 17% of the variance (eigenvalue = 2.49). Factor 4, labelled Organizational Self-Reliance, included the attribute items focused on vendor independence and accounted for 12% of the variance (eigenvalue = 1.80). Only one attribute item – 'Need for application functionality not available in commercial software' – loaded poorly on all four factors and was dropped from the scale during subsequent analyses. The standard factor scores were calculated and were subsequently evaluated as predictors in a binary logistic regression model.

Binary logistic regression with backward elimination was selected to determine what factors/drivers contribute to the decision to select or not select an OSS LMS, along with the relative strength of each of the factors/drivers as selection predictors. This regression model is used to predict (and thus, explain) a dependent variable that is binary or dichotomous, and the independent variables or predictors are of any type (Hosmer & Lemeshow 2000). The model begins by including all predictors and testing them one by one for statistical significance, deleting any that are not significant. Further, this regression model does not make any of the key assumptions of normality, homoscedasticity, or measurement level that are characteristic of linear regression. The backward method is also appropriate for a situation in which there is little or no research upon which to base hypotheses for testing and when the researcher seeks to reduce the likelihood of making a type II error, which is a false negative (Field 2009).

In this study, the predicted outcome or dependent variable is selection of an OSS LMS, and is drawn from the yes (coded '1') or no (coded '0') responses to the question, 'Has your institution either deployed or is your institution in the process of deploying an open-source learning management system?' The independent variables are:

- The four factors extracted from the principal component factor analysis – Student Learning, System Support, System Stakeholders, and Organizational Self-Reliance – representing the OSS LMS selection criteria, with the factor score coefficients computed for each respondent as input into the model.
- Five Carnegie Classification dummy variables: originally a single nominal variable whereby respondents indicated their institution's assigned classification as documented in the US Department of Education's Integrated Postsecondary Education Data System (IPEDS) (National Center for Education Statistics, n.d.). There are six basic categories as set down by the Carnegie Commission on Higher Education (The Carnegie Foundation for the Advancement of Teaching, n.d.): Associates, Baccalaureate/Associate, Baccalaureate, Masters, Doctoral/Research, and Special Focus Institution. Chi-square testing suggested a relationship between Carnegie Classification and OSS LMS selection, $\chi^2(5, N = 210) = 15.869$, $P = 0.007$, prompting the selection of Carnegie Classification as a predictor variable. However, to include this nominal variable in the regression model, dummy variables for k–1 categories $(6 - 1 = 5)$ were created, with the Doctoral/Research category selected as the baseline to which all the other Carnegie classifications were compared, and using '0' and '1' to indicate whether or not a particular respondent's institution is or is not of that specific classification.
- Two Governance dummy variables: a nominal variable whereby respondents indicated their institution's governance structure as public, private not-for-profit, or private for-profit. Chi-square testing, $\chi^2(2, N = 210) = 3.138$, $P = 0.049$, suggested that there may be a relationship between OSS LMS selection and an institution's governance structure, prompting the selection of Governance as a predictor variable. Two dummy variables – public and private not-for-profit – were created using private for-profit as the baseline.
- One Previous OSS Experience dummy variable: chi-square testing indicated that there may be a relationship between selection vs. nonselection of an OSS LMS and previous experience with OSS as measured by deployment of OSS operating systems such as Linux [$\chi^2(6, N = 210) = 41.115$, $P = 0.000$]. This nominal variable originally consisted of seven categories describing various stages of deployment. This variable was re-coded into a binary variable in which all 'live' implementations are coded as '1' and all other responses as '0'.

P-values less than 0.05 were considered statistically significant, and the Hosmer–Lemeshow statistic was used to assess the model's goodness-of-fit (Hosmer & Lemeshow 2000). Estimated coefficients and their associated standard errors were calculated, along with the 95% confidence interval around the estimated probabilities of considered outcomes for each case. The relatively small sample size of the study precluded predictive validation using an independent test data set. Instead, the model's predictive ability was assessed by cross-classifying cases according to their reported outcome status and their predicted status, with 0.5 as the predicted probability cutoff. Predictive ability was further assessed by refitting the model to a randomly selected subset of 70% of the cases, then using the resulting model to predict the probability of the outcome in the 30% of cases excluded during model fitting.

Results

Table 2 presents the results of the final step of the binary logistic regression with backward elimination. Of the 12 predictor variables, only five – Previous Experience with OSS, Masters Institution, Organizational Self-Reliance, Public Governance, and Student Learning – were able to differentiate a 'go' from a 'no-go' decision (–2 Log likelihood = 177.193; $\chi^2(5) = 73.555$; $P = 0.000$). The dummy variables Special Focus institutions and Associate institutions failed to meet the 0.05 significance criterion at steps 7 and 6, respectively, and were dropped from the model; Private Governance was dropped at step 5; Baccalaureate/Associates at step 4; Baccalaureate at step 3, and; System Support (factor 2) and System Stakeholders (factor 3) at step 2.

The model's goodness-of-fit as measured by the Hosmer and Lemeshow test [$\chi^2(8) = 10.508$, $P = 0.231$] was not statistically significant, indicating that the model fits the data well. Looking at the Wald chi-Square statistic, which tests the unique contribution of each

Table 2. Summary of logistic regression analysis for variables predicting higher education institutions' selection of an open-source software learning management system (OSS LMS) (N = 210).

Variable	β	SE β	Wald	d.f.	P	Odds ratio	Inverse odds ratio
Previous experience with OSS (no previous experience with OSS)	−1.959	0.404	23.561	1	0.000	0.141	7.092
Masters institution (doctoral/research institution)	−1.118	0.460	5.916	1	0.015	0.327	3.058
Factor 4 – organizational self-reliance	−0.915	0.214	18.219	1	0.000	0.401	2.493
Public governance (private, for-profit governance)	−0.890	0.404	4.855	1	0.028	0.411	2.433
Factor 1 – student learning	−0.561	0.198	8.064	1	0.005	0.571	1.751
Constant	4.702	0.803	34.302	1	0.000	110.144	

Note: Variables enclosed in parentheses () indicate the relevant baseline groups.
d.f., degrees of freedom.

predictor while holding constant the other predictors, each of the five predictors met the conventional 0.05 standard for statistical significance. The model as a whole explained between 30.8% (Cox and Snell R^2) and 43.1% (Nagelkerke R^2) of the variance in the OSS LMS selection decision. The overall rate of correct classification was 82.0%, with a sensitivity – the percentage of occurrences correctly predicted – of 89.7% and a specificity or percentage of nonoccurrences correctly predicted, of 65.6%.

All five of the predictors have negative β coefficients and odds ratios that are less than 1.0. To interpret these odds ratios, this study uses the inverse odds ratio (IOR) procedure developed by DesJardins (2001). IOR transforms the odds ratios for negatively related coefficients by applying the formula (1/odds ratio). Using this procedure, the IORs for the five predictors were computed and are displayed in the last column of Table 2.

For institutions in the study sample without previous OSS experience, the probability of selecting an OSS LMS is about seven (IOR = 7.092) times higher than for institutions with previous OSS experience, holding all other variables constant. The odds of selecting an OSS LMS among doctoral/research institutions is three (IOR = 3.058) times higher than among Masters institutions, while the odds of selecting an OSS LMS among private, for-profit institutions are more than twice (IOR = 2.433) as high than for public governance institutions. Lastly, for higher education institutions in the sample, the odds of excluding considerations related to Organizational Self-Reliance (factor 4) are more than double (IOR = 2.493) that of those including Organizational Self-Reliance considerations when selecting an OSS LMS, while the probability of selecting an OSS LMS is nearly twice (IOR = 1.751) as high for institutions excluding considerations related to Student Learning (factor 1) than those including Student Learning considerations.

To test the model's validity, the data set was randomly split into a 70% estimation sample and a 30% validation sample. The estimation sample was used to develop the model and the validation sample used to estimation the model's applicability to cases not used in model development. The binary logistic regression of the estimation sample yielded the same set of five predictors that was produced by the regression model of the full data set. The Hosmer and Lemeshow test [$\chi^2(8) = 6.916$, $P = 0.546$] was not statistically significant, indicating that the estimation sample model was a good fit. The estimation sample model explained between 40.7% (Cox and Snell R^2) and 56.6% (Nagelkerke R^2) of the variance.

As shown in Table 3, the overall correct classification was 80.6% for the estimation sample and 77.0% for the validation sample. Model sensitivity or the percentage of occurrences predicted correctly was 83.9% and 90.7% for the estimation and validation samples, respectively. Model specificity – the percentage of nonoccurrences correctly predicted – was 73.9% for the estimation sample and 40.4% for the validation sample. This successful validation affirms the accuracy of the model developed with the full data set.

Discussion

The model

The purpose of this study was to construct a model that identifies and prioritizes (in terms of relative impact)

Table 3. Estimation and validation models classification.

Observed	Predicted			Predicted		
	Estimation model (N = 147)			Validation model (N = 61)		
	Select OSS LMS	Not select OSS LMS	Percentage correct	Select OSS LMS	Not select OSS LMS	Percentage correct
Select OSS LMS	82	16	83.9	39	8	90.7
Not select OSS LMS	12	36	73.9	4	10	40.4
Overall percentage correct:			80.6			77.0

the pedagogical, technical, and institutional profile factors that contribute to the decision to select (or not select) an open-source LMS campus-wide. Carnegie Classification was found to have a strong impact on a 'go' decision, with Masters institutions less likely than doctoral/research institutions to select an open-source LMS. These results are consistent with the latest administration of the Campus Computing survey (Green 2010), as well as results from the EDUCAUSE Core Data Service annual survey (EDUCAUSE Core Data Service 2009), which indicated that the highest adoption of OSS LMS remains among the Doctoral/Research institutions, although Moodle has a strong presence among 4-year private (Masters) institutions. The finding that public governance institutions were less likely than private for-profit institutions to select an open-source LMS was not unexpected. Like other organizations in the public sector, higher education adoption of new technologies can be challenging because of higher levels of public scrutiny and calls for evidence of organizational effectiveness. Somewhat surprising, however, was the inverse relationship between previous OSS experience and the decision to select an OSS LMS, since open-source operating systems have a fairly strong presence in US higher education, particularly as a teaching tool in the Computer Science curriculum (Williams van Rooij 2007a; Green 2009).

One possible explanation for the inverse relationship between previous OSS experience on OSS LMS selection is the limited number of options for implementing open-source operating systems. Until recently, institutions had to either implement on their own or subscribe to third-party vendors. Anecdotal evidence indicates that implementation results have been mixed (EDUCAUSE, n.d.), which would temper enthusiasm for undertaking another open-source implementation, particularly in the mission-critical area of teaching and learning. Another possible explanation is the growing focus on technology solutions that cross operating systems and on desktop software applications – either on-site or remotely hosted – that are agnostic to the various operating systems (Center for Digital Education 2010). Institutions can remain with their current operating system(s), while taking advantage of new technologies to increase operating efficiency and effectiveness. Consequently, an open-source operating system would become less of a factor in the decision to select or not select an open-source LMS.

The role of the factors Student Learning and Organizational Self-Reliance was also unexpected. One possible explanation for the inverse relationship between OSS LMS selection and each of these factors may lie in the relatively small body of evidence demonstrating the impact of open source on either student outcomes or organizational efficiencies. Only recently have institutions begun sharing their OSS success stories by placing their own OSS assessment models and migration experiences in the public domain (Uys & Morton-Allen 2007; Chao 2008; O'Laughlin & Borkowski 2008). Live case studies with best practices for selection and implementation that include information about total cost of ownership of OSS vs. commercial software applications, as well as strategies for faculty support are also emerging (Lakhan & Jhunjhunwala 2008; Oakland University 2009). As more institutions share what they have learned about both the process and the impact of OSS selection, subsequent iterations of the model developed in this study should demonstrate a strong, positive impact for student learning and organizational self-reliance.

Limitations

When interpreting the impact of the predictors, there are some limitations to consider. First, the study only included the specific pedagogical, technical, and institutional profile characteristics identified in a previous study on OSS in higher education (Williams van Rooij 2007b; Williams van Rooij 2011a). There may be other factors that contribute to the decision to select an OSS LMS. For example, organizational culture and openness to new technologies may affect the decision process.

The role of cultural 'fit' and OSS selection has achieved some recognition in the literature. For example, two published guidelines to assist institutions in assessing the 'fit' of their organization with open source are the Business Readiness Rating and the Open-Source Maturity Model. The Business Readiness Rating (Business Readiness Rating 2006) provides a framework advanced by developers from education and industry to assess the organizational fit of OSS based on seven weighted criteria: functionality, including communication, collaboration, learner assessment, and instructional management tools; usability, particularly the ease with which faculty and students can become proficient in using the software; the availability and quality of user-maintained documentation for system administrators, faculty, and students; the size and activity level of the developer community, as measured by the e-mail forums and number of people contributing code; the number and severity of security alerts and the speed with which they are addressed; the amount and quality of volunteer and commercial support available, and; the number and size of current installations at other institutions. The Open-Source Maturity Model (Navica 2008) enables organizations to self-identify as to how they rate themselves in terms of overall maturity in information technology adoption. Based on where they fall in the maturity rankings, organizations then assess OSS systems on features/functions, support, documentation, training, product integration, and available professional services.

A second limitation of the present research is that the model does not take into account any differences in the process of decision-making among institutions. Although the CIO and the CAO are partners in the decision to select (or not select) an OSS LMS, who provides the information upon which to base decisions, how decisions are made, and who is accountable for those decisions, varies from institution to institution (Eade 2010). Individual authority and stakeholder relationships are particularly complex in organizations characterized by participatory decision-making (Simon 1997), which in turn, may affect decisions about which technologies should be in the institution's choice set.

A third limitation concerns the procurement process itself. When selecting enterprise-wide software systems, institutions of higher education normally issue requests for proposals (RFPs) to objectively select and evaluate products. The RFP includes a variety of questions, such as product features/functions, training and support, maintenance costs, license fees, and total cost of ownership, all of which are based on procurement among a selection of vendors. Because OSS has no license fees, and costs and resources vary by institution or by whether or not a third-party vendor is used to implement the open-source product, calculating the true cost (and value) of an OSS LMS can be tricky. Consequently, the willingness and ability to engage in a non-traditional procurement process may affect technology selection decision-making. However, this challenge is being addressed. The IMS Global Learning Consortium, an organization dedicated to advancing the impact of technology on learning, has launched a project to develop a common set of standards for LMS RFPs that would enable institutions to evaluate commercial and open-source systems in a comparable manner (IMS Global Learning Consortium 2010).

Conclusions

Although there are many models for evaluating LMS, relatively little research has been reported regarding the selection of open source LMS. The present research revealed that an institution's Carnegie Classification, previous experience with OSS, focus on student learning, and commitment to organizational self-reliance were all predictive of the institution's decision to opt in or opt out of an open-source LMS. Although the model presented here is by no means definitive, it does extend the discussions surrounding open-source selection and adoption beyond the traditional software sytem evaluation paradigms and provides insights about the role of influencers other than features of the LMS product itself. The model also suggests opportunities for further research in terms of: (1) identifying additional elements (e.g. organizational cultural fit and attitudes toward risk) that would strengthen the model's predictive power; (2) collecting and analyzing a large data set that would enable comparison of institutions that utilize third-party commercial vendors for OSS implementation and maintenance services versus institutions utilizing in-house talent and resources; and (3) determining the extent to which specific institutional case studies that have been placed in the public document align with the present model. Given the ongoing pressure to demonstrate technology's contribution to both learning and organizational efficiencies, there will continue to be a need to maximize technology investments, while providing quality post-secondary education. As such, predictive models that identify the key drivers of OSS LMS selection can assist institutions in strengthening their ability to determine whether or not an OSS LMS should be part of their choice set.

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Supporting information

Additional Supporting Information may be found in the online version of this article:

Table S1. LMS evaluation models.
Table S2. Summary of exploratory factory analysis results for OSS LMS selection criteria using principal components factor analysis with Varimax rotation ($N = 210$).
Table S3. Output of stepwise binary logistic regression analysis of variables predicting higher education selection of an OSS LMS ($N = 210$).

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