McGill, T.J. and Klobas, J.E. (2005) The role of spreadsheet knowledge in user developed application success. Decision Support Systems, 39 (3). pp. 355-369.

The role of spreadsheet knowledge in user-developed application success

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Abstract

Spreadsheets are the most commonly used tool for end user development of applications, and organizations depend heavily upon them for decision making. This paper reports on a study to investigate the role of spreadsheet knowledge in the successful use of spreadsheet applications. It considers both the spreadsheet knowledge of the user developer and the spreadsheet knowledge of the user and tests a model of the effect of spreadsheet knowledge on the success of a user-developed spreadsheet application. Spreadsheet knowledge was shown to be important in two ways. It influences the quality of the system being developed, but it also acts directly upon the individual impact of the application. Successful use appears to require sufficient knowledge to understand and, if necessary, alter the application.

Keywords

End user computing; End user development; Spreadsheet knowledge; User-developed application success

1. Introduction

An end user developer is someone who develops applications to support his or her work or the work of other end users. The applications developed are known as user-developed applications (UDAs). End user development of applications forms a significant part of organizational systems development, with the ability to develop small applications forming part of the job requirements for many positions [24]. Spreadsheets are the most commonly used tool for end user development of applications [55] and organizations depend heavily upon spreadsheet applications for both processing and decision making.

Spreadsheet applications are used for a wide variety of organizational tasks. In a survey to determine the types of applications developed by end users, Rittenberg, Senn, and Bariff [41] identified over 130 different types of applications and the majority of these were developed using spreadsheets. Many of these were accounting related but marketing, operations and human resources applications were also heavily represented. The accounting applications most frequently implemented were budget analysis, financial analysis, financial performance forecasting, and 'what-if' analysis. Early studies tended to find that UDAs were typically used for queries, reports and simple analyses (e.g., [42] and [45]). However, the range of tasks has expanded as the sophistication of both software development tools and user developers has increased. This has led to a degree of convergence with corporate computing, so that the tasks for which UDAs are developed are less distinguishable from tasks for corporate computing applications [34].

Despite their importance, organizations tend to have little formal evaluation of UDAs and rely heavily on end users' evaluations of system quality and fitness for use [37]. This reliance assumes that end user developers are sufficiently knowledgeable to develop accurate and reliable applications, and that the users of these applications—who are not necessarily the same people as the users who developed them—are sufficiently knowledgeable to use them successfully. This paper reports on a study to investigate the role of spreadsheet knowledge in the successful use of spreadsheet applications. It considers both the spreadsheet knowledge of the user developer and the spreadsheet knowledge of the user and tests a model of the effect of spreadsheet knowledge on the success of a user-developed spreadsheet application.

2. Background

This research addresses two principle propositions, based on the two sources of knowledge needed for successful use of a user-developed spreadsheet application: the spreadsheet knowledge of the user developer and the spreadsheet knowledge of the developer:

(a) The spreadsheet knowledge of the user developer affects the success of the spreadsheet application.

(b) The spreadsheet knowledge of the user affects the success of the spreadsheet application.

In this section, we consider the nature of spreadsheet application success and the chain of effects that may mediate the relationship between knowledge and success before proposing a set of hypotheses and a model that enable us to examine the proposed relationship between spreadsheet knowledge and success.

2.1. The nature of spreadsheet application success

Edberg and Bowman [16] noted that there has been little direct empirical examination of the effectiveness of end users as application developers. Similarly, Shayo et al. [54] (p. 8) noted that 'while research continues to grow on IS success, it remains scanty on measurement of end user success'. They attributed this lack of research to the fact that UDAs are rarely tracked formally by organizations and that users may be reluctant to allow measurement of the efficiency or effectiveness of their applications. They suggested that the most commonly used measure of success, user satisfaction, is less threatening and easier to obtain than independent measures. However, this may be problematic because users are asked to place a value on something about which they may not be objective [32].

Many of the studies investigating application success have been laboratory experiments designed to identify the impact of application use on individual users. In these studies, individual impact has been defined and measured using variables such as time to complete a task [6], confidence in the decision made [20], and ability to forecast firm performance [25], but individual impact can also be interpreted in a number of other ways. DeLone and McLean [15] have noted that individual impact is the most difficult information systems success category to define in unambiguous terms. For example, impacts such as whether the application has provided the user with a better understanding of the decision making process or whether it has resulted in role expansion for them might be considered.

DeLone and McLean's [15] classification of information systems success measures identified several other levels at which success might be measured. As with organizational information systems, there is a need to bring together the disparate measures of UDA success and to look at the relationships between them [38]. Rivard and Huff [43] and Amoroso and Cheney [2] and [3] proposed and tested early models of UDA success. Shayo, Guthrie, and Igbaria [54] discussed the relevance of both the DeLone and McLean [15] and Seddon [49] models of information system success to end user computing and called for a more complete and integrated model. McGill, Hobbs, and Klobas [33] tested a modified version of DeLone and McLean's model of information systems success in a study that involved end user spreadsheet development and use. That study highlighted that user perceptions of information systems success play a significant role in the UDA domain, but it also suggested that there might be a direct relationship between system quality and individual impact. In this study, we therefore consider the success measures system quality and user satisfaction, along with their association with the common measure of spreadsheet application success, individual impact.

2.2. Relationships between spreadsheet knowledge and spreadsheet application success

Organizations invest in end user developer training under the assumption that it will result in applications of improved quality and in improved outcomes in terms of the successful use of applications [12] and [14]. The implicit assumption is that training leads to greater levels of end user knowledge and skill, which, in turn, lead to better quality applications. The research findings have, however, been mixed. In a survey of 254 end users, Chan and Storey [9] found no relationship between training and self-reported spreadsheet proficiency. This lack of association between training and outcomes may, however, be an artifact of the use of selfreport measures. In a study on end user development of databases, Agboola [1] found a strong relationship between the data modeling knowledge of the developer and database quality. Kreie [26] found no relationship between spreadsheet knowledge and spreadsheet quality. However, she speculated that this was because all of the subjects in her study had high levels of spreadsheet knowledge. In order to test the effect of end user developer spreadsheet knowledge on system quality, it was hypothesized for this study that:

H1. The system quality of a UDA increases as the end user developer's level of spreadsheet knowledge increases.

While there has been an implicit assumption in the organizational information systems literature that user perceptions of system quality reflect ‘actual’ system quality [15], there have been concerns expressed in the literature about the ability of end users to make realistic judgments of system quality (e.g., [16], [27] and [54]). In a study of end user development of spreadsheet applications, McGill, Hobbs, and Klobas [33] found no relationship between system quality as assessed by independent experts and system quality as assessed by end user developers. It was hypothesized that system quality influences perceived system quality, but that this relationship may be perturbed by the influence of the spreadsheet knowledge of the user (see H3). It was therefore hypothesized that:

H2. Perceived system quality increases as system quality increases.

In reporting on a study that investigated the ability of end users to assess the quality of applications they develop, McGill [30] suggested that end users with little experience might erroneously consider the applications they develop to be of high quality. End users' perceptions of system quality might be compromised because of lack of knowledge. In particular, end users with low levels of knowledge may not recognize system quality problems and hence may have inflated perceptions of quality, whereas end users with high levels of knowledge may become more critical. Yaverbaum and Nosek [56] raised this possibility with respect to the role of training. Therefore, it was hypothesized that:

H3. Perceived system quality decreases as the end user's level of spreadsheet knowledge increases.

There is previous evidence to support the existence of a positive relationship between perceived system quality and user satisfaction in the UDA domain [33] and [44]. It was therefore hypothesized that:

H4. User satisfaction reflects perceived system quality.

The literature on individual impact suggests the possibility that system quality may have both a direct effect on impact and one mediated by user satisfaction. Hubona and Cheney [23] found not only a strong relationship between user satisfaction and two objective measures of user performance, but also a significant direct relationship between system characteristics and user performance. Similarly, McGill [29] observed both direct and indirect (via user satisfaction) effects on the individual impact of UDAs. Therefore, it was hypothesized that:

H5. Individual impact reflects user satisfaction.

H6. Individual impact reflects system quality.

Hypotheses 1–6 are consistent with what might be expected for the use of organizational information systems. However, UDAs are generally of lower quality than organizational systems [8], [16] and [36], and successful use may require more from the user than would successful use of an organizational system. In particular, use of user-developed spreadsheet applications may require substantial prior knowledge because of a lack of separation between data and processing [22], [39] and [46]. For example, if data is embedded within formulas, the user must be able to edit formulas in order to update data. Hence, it was hypothesized that:

H7. Individual impact reflects the level of spreadsheet knowledge of the application user.

The hypothesized relationships are represented graphically in Fig. 1.

3. Method

3.1. Participants

The target population for this study consists of end users who develop their own spreadsheet applications and who use spreadsheets developed by themselves or others. Recruitment occurred firstly through a number of advertisements placed in local newspapers calling for volunteers, these were followed by e-mails to three large organizations that had expressed interest in the study and finally word of mouth brought forth some additional participants. Participants were given Australian$20 to compensate them for parking costs, petrol, and inconvenience and were also offered a 1-h training course entitled ‘Developing Spreadsheet Applications’ as an additional incentive to participate. While being essentially a convenience sample, the participants covered a broad spectrum of ages, spreadsheet experience and training. Of the 159 participants, 32.7% were male and 67.3% female and their ages ranged from 14 to 77 with an average age of 42.7. Participants reported an average of 4.5 years experience using spreadsheets (with a range from less than 1 year to 21 years).

3.2. Procedure

Fourteen separate experimental sessions of approximately 4 h were held over a period of 5 months. Each session involved between 7 and 17 participants (depending on their availability). Each experimental session consisted of three parts.

In Part 1, participants were asked to complete a questionnaire to provide demographic information about themselves and information about their background with computers and spreadsheets. The questionnaire also tested their knowledge of spreadsheets.

In Part 2, the participants were given a problem statement and asked to develop a spreadsheet to solve it using Microsoft Excel. The problem related to making choices between car rental companies. Participants were provided with blank paper to use for planning if they wished, but otherwise were left to develop the application as they wished. They were encouraged to treat the development exercise as they would a personal or work task, rather than as a test. Participants could use on-line help or ask for technical help from the two researchers present in the laboratory during each session.

Once all participants in the session had completed developing their spreadsheet, they undertook Part 3 of the session. Each participant was given a floppy disk containing a spreadsheet developed by another participant in the session. They then used that spreadsheet to answer 10 questions relating to making choices about car rental hire and the time taken to answer these questions was recorded. After answering (or attempting to answer) the questions, they completed a questionnaire that included items to measure perceived system quality of the UDA and user satisfaction with it. Each participant thus developed an application themselves and used an application developed by another end user. This design was chosen as a device to study the effect of user knowledge separately from developer knowledge.

3.3. Instruments

The development of the research instruments for this study involved a review of many existing survey instruments. To ensure the reliability and validity of the measures used, previously validated measurement scales were adopted wherever possible.

3.3.1. Spreadsheet knowledge

Cheney and Nelson [10] made an early attempt to measure end user computing abilities, developing an instrument that measured three dimensions: technical abilities, modeling abilities, and applications abilities. Bowman [7] noted that the systems development expertise of an end user developer is a function of two dimensions: expertise in application development methods and expertise with the development tool or language used to develop the application. Spreadsheet knowledge is therefore defined in this study as: the knowledge of spreadsheet software features and spreadsheet development practices that end user developers draw upon when developing and using spreadsheet applications. Thus, spreadsheet knowledge determines what end user developers are capable of doing rather than what they actually do. The instrument used to measure spreadsheet knowledge was based upon an instrument used by McGill and Dixon [31]. That instrument was developed using material from several sources including: Kreie's [26] instrument to measure spreadsheet features knowledge; spreadsheet development methodologies from Ronen, Palley, and Lucas [46] and Salchenberger [47]; and Rivard et al.'s [44] instrument to measure the quality of UDAs. The final instrument contained 25 items. Each item was presented as a multiple choice question with five options. In each case, the fifth option was ‘I don't know’ or ‘I am not familiar with this feature’. Nine of the items related to knowledge about the features and functionality of spreadsheet packages, eight items related to development process and eight items related to spreadsheet quality assurance.

3.3.2. System quality and perceived system quality

System quality relates to the quality of a spreadsheet and is concerned with issues such as reliability, maintainability, ease of use, etc. In this study, end user perceptions of system quality are considered to be a separate construct from system quality as assessed by independent experts. The items used to measure both system quality and perceived system quality were obtained from the instrument developed by Rivard et al. [44] to assess the quality of UDAs. Rivard et al.'s instrument was designed to be suitable for end user developers to complete, yet to be sufficiently deep to capture their perceptions of components of quality. For this study, items that were not appropriate for the applications under consideration (e.g., specific to database applications) were excluded. Minor adaptations to wording were also made to reflect the environment in which application development and use occurred. The resulting system quality scale consisted of 20 items, each scored on a Likert scale of 1 to 7 where (1) was labeled ‘strongly agree’ and (7) was labeled ‘strongly disagree’ (see Appendix A for the items).

In addition to the participants' assessments of system quality, the system quality of each application was assessed by two independent assessors using the same set of items. Both assessors were information systems academics with substantial experience teaching spreadsheet design and development. The two final sets of independent assessments were highly correlated ($r=0.80$, $p<0.001$) and averages of the ratings for each item were used in the analysis.

3.3.3. User satisfaction

User satisfaction relates to the attitude or response of an end user towards a spreadsheet application. Given the confounding of user satisfaction with information quality and system quality in some previous studies [50], items measuring only user satisfaction were sought. Seddon and Yip's [51] four-item, seven-point semantic differential scale that attempts to measure user satisfaction directly was used in this study. A typical item on this scale is ‘How effective is the system?’ measured from (1) ‘effective’ to (7) ‘ineffective’ (see Appendix A for the items).

3.3.4. Individual impact

As discussed previously, the individual impact of a UDA could be related to a number of measures such as impact on performance, understanding, decision making, or motivation. Individual impact was measured in two different ways in this study: accuracy of decision making (number of questions correct) and time taken to answer a set of questions. These measures were also used by Goodhue, Klein, and March [19] in their study on user evaluations of systems.

For this study, 10 questions involving the comparison of costs of car rental companies under a variety of scenarios were created. The questions ranged from comparison of the three firms when no excess kilometer charges are imposed through to questions where excesses are applied and basic parameters are assumed to have changed from those given in the original problem description. A typical question is ‘Which rental company is the cheapest if you wish to hire a car for 6 days and drive approximately 1500 kms with it?’ Participants were asked to provide both the name of the cheapest firm and its cost. The questions were piloted by four end users and slight changes made to clarify them.

3.4. Data analysis

The relationships in the model were tested using structural equation modeling (SEM). Maximum likelihood estimates of the measurement and structural models were made using Amos 4.

Three criteria were used to test model quality: goodness of fit, variance explained, and the significance of each path in the model. Goodness of fit was measured by the likelihood ratio chi-square (χ^2), the ratio of χ^2 to degrees of freedom (χ^2/df), the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the root mean square error of approximation

(RMSEA), and the Tucker–Lewis index (TLI). The guidelines used for good model fit were: a non-significant χ^2 (p>0.05); a χ^2/df of less than 3:1 [11]; GFI of 0.9 or greater [48]; AGFI of greater than 0.8 [52]; RMSEA of less than 0.05 [48]; and TLI of 0.90 or greater [21]. The R^2 values of the structural equations for the dependent variables provide an estimate of variance explained [21] and, therefore, an indication of the success of the model in explaining these variables. The third criterion on which the model was evaluated was the statistical significance of the estimated model coefficients. A conservative significance level of 0.01 was specified. If the hypothesized model is a valid representation of UDA success, all proposed relationships in the model should be significant.

Although both structural and measurement models can be estimated simultaneously using SEM, the measurement model was developed first in this study. This approach was appropriate because not all the measures had been tested in the UDA domain before, and because the sample size was small [4].

Two potential items to measure individual impact were included in the design of this study: number of correct decisions; and time to make decisions. Examination of the data revealed that a sizeable proportion of participants appeared to have quickly discovered that they were unlikely to be able to answer the questions correctly, and hence abandoned the attempt. This suggests that time to make decisions was not an appropriate indicator of individual impact for this study. It was therefore decided to retain number of correct decisions as a single item indicator for individual impact in the structural model evaluations.

After indicator variables with low inter-item correlations were omitted, SEM was used to estimate a one-factor congeneric measurement model for each multi-item construct. Validity and unidimensionality of each of the constructs were demonstrated when all included indicators were statistically significant and the one-factor measurement model that represented the construct had acceptable fit [21]. Three estimates of reliability were calculated for each construct: Cronbach alpha coefficient, composite reliability, and average variance extracted. For unidimensional scales, values for Cronbach alpha of 0.7 or higher indicate acceptable internal consistency [35]. A commonly used threshold value for composite reliability is 0.7 [21] and a variance extracted value greater than 0.5 indicates acceptable reliability [21]. The three measures of reliability were all acceptable for each scale (see Table 1).

The measurement model for each construct provided a composite value for inclusion in the structural model; variables estimated in this way are described as ‘composite variables’. Using composite variables has been shown to reduce random error and enable more stable and reliable estimates of model constructs [5] and [28]. Composite variables were created for system quality, perceived system quality and user satisfaction using the factor score weights reported by Amos 4. The loading of each composite variable on its associated latent variable and the error associated with using the composite variable to represent the latent variable were estimated as described by Hair et al. [21]. Table 1 provides a summary of the information from the measurement models used to specify parameters in the structural models.

Once measurement models were established, it was possible to estimate the hypothesized structural model. This model was evaluated on three criteria: goodness of fit, the ability of the model to explain the variance in the dependent variables, and the statistical significance of estimated model coefficients.

4. Results

The results of the analysis are summarized in Table 2 and Table 3 and illustrated graphically in Fig. 2. The goodness of fit measures included in Table 2 indicate a good fit between model and data on all the measured criteria: χ^2 is non-significant, χ^2/df is less than 3:1, GFI and TLI are greater than 0.9, AGFI is greater than 0.8, and RMSEA is less than 0.05. The model explained a satisfactory proportion of the variance in spreadsheet application success. The R^2 values reported in Fig. 2 show that it explained 23.1% of the variability in system quality, 39.6% of the variability in perceived system quality, 55.3% of the variability in user satisfaction, and 34.0% of the variability in individual impact.

The path coefficients for the model are reported as raw estimates with *t* values in Table 2 and as standardized estimates in Fig. 2. While five of the seven hypothesized direct relationships were supported, two—the relationship between user spreadsheet knowledge and perceived system quality, and the direct relationship between system quality and individual impact—were not. Thus, the model was partially supported. Table 3 reports the standardized total effects (direct plus indirect) estimated for the proposed model, that is, the total effects of each variable in the model on subsequent dependent variables. This table shows that, while there may not be a direct relationship between system quality and individual impact, there is an indirect relationship, mediated by perceived system quality and user satisfaction.

The implications of these results for the individual hypotheses are:

- H1 is supported: The system quality of a UDA increases as the end user developer's level of spreadsheet knowledge increases.
- H2 is supported: Perceived system quality increases as system quality increases.
- H3 is *not* supported: Perceived system quality is not related to the end user's level of spreadsheet knowledge.
- H4 is supported: User satisfaction reflects perceived system quality.
- H5 is supported: Individual impact reflects user satisfaction.
- H6 is supported, but not in the form drawn in the structural model. While individual impact does reflect system quality, its effect is indirect, being mediated by perceived system quality and user satisfaction.
- H7 is supported: Individual impact reflects the level of spreadsheet knowledge of the application user.

In conjunction with Fig. 2, Table 3 allows us to compare the ways in which user developer spreadsheet knowledge and (non-developer) user spreadsheet knowledge affect spreadsheet application success:

- User *developer* spreadsheet knowledge affects system quality, and consequently, user perceptions of system quality and user satisfaction with use. Through user satisfaction, it has a weak effect on the individual impact of spreadsheet use.
- Non-developer *user* spreadsheet knowledge does not affect perceptions of system quality or user satisfaction, but has a relatively strong effect on individual impact.

From Fig. 2 and Table 3, we can see that the total effect of developer spreadsheet knowledge on individual impact for the user is much lower than the effect of the user's own spreadsheet knowledge. We can also see that the effects of user spreadsheet knowledge and user satisfaction on individual impact are independent of one another, and of about equal weight.

5. Discussion

In the study described here, the success of the spreadsheet application was affected by spreadsheet knowledge. Both of the propositions about the effect of spreadsheet knowledge were supported: the success of the spreadsheet application reflected both the spreadsheet knowledge of the user developer and the spreadsheet knowledge of the user (who was not the developer).

This research further demonstrates that the ways in which each actor's spreadsheet knowledge affects success vary. The spreadsheet knowledge of a spreadsheet developer influences all of the measured indicators of spreadsheet application success by influencing system quality from which users' perceptions of system quality and user satisfaction arise. The overall effect of developer spreadsheet knowledge on the individual impact of spreadsheet use is, however, low. On the other hand, user spreadsheet knowledge is not associated with perceived system quality or user satisfaction. Instead, it has a direct effect on the individual impact of spreadsheet use, an effect independent of, and of a similar magnitude to user satisfaction.

This overview leads to several considerations about the relationships observed in this research.

5.1. Developer spreadsheet knowledge influences system quality

As hypothesized, user developers with greater levels of spreadsheet knowledge developed spreadsheets of higher system quality. This finding is consistent with the results of Agboola [1] who found a strong relationship between data modeling knowledge and the quality of database implementations. However, the findings differ from those of Kreie [26] who found no relationship between knowledge of spreadsheets and spreadsheet quality. Kreie speculated that the lack of relationship in her study was because all of her participants had relatively high levels of spreadsheet knowledge (an average of 86% on her knowledge test, with little variability). She concluded that beyond a certain level, knowledge of spreadsheet software is probably not a determining factor in the quality of spreadsheets. The instrument used to measure spreadsheet knowledge in Kreie's study differs from the instrument used in this study in that it focuses on only one aspect of spreadsheet knowledge: knowledge of spreadsheet features. A consideration of other facets of spreadsheet knowledge could perhaps have provided her with a clearer insight into the relationship. Nevertheless, only 23% of the variability in system quality in this study was explained by developer knowledge more broadly defined to include knowledge of development practices as well as spreadsheet features, so other factors that influence system quality should be considered in research designed to understand how spreadsheet quality is achieved.

5.2. Perceived system quality reflects system quality

As hypothesized, independently assessed system quality had a significant positive influence on perceived system quality. This finding supports the implicit assumption in much of the organizational information systems literature that user perceptions of system quality reflect ‘actual’ system quality [15]. This finding is, however, in contrast to the lack of relationship found in McGill et al.'s [33] test of Delone and McLean's model of information systems success in the UDA domain, and to the concerns expressed in the literature about the ability of end users to make realistic judgments of system quality [16], [27] and [54]. The difference in results between this study and McGill et al.'s study may be due to the size and complexity of applications being considered. The applications developed in this study were probably smaller and less complex than is the norm for user development [22], and this would contribute to ease of quality assessment. The difficulty of assessing system quality is likely to be magnified as the size and complexity of applications increases.

The fact that end users' perceptions of the quality of the small to moderate UDAs in this study are consistent with those of independent assessors should, nonetheless, provide some reassurance to organizations that rely heavily upon end users assessments of quality and fitness for use. Organizations should be able to rely on end users' judgments for these kinds of applications. However, if the applications developed in McGill's [33] study are more typical of those being developed in the workplace, then the difference in results between these two studies highlights the need to either increase end users' levels of development knowledge via training so that they can cope with applications of greater complexity, or to provide other forms of support for development such as intelligent tool support [53].

5.3. User satisfaction reflects perceived system quality

As hypothesized, perceived system quality had a strong positive effect on user satisfaction. This is consistent with previously published results [33], [44] and [50].

5.4. Individual impact reflects user satisfaction

As hypothesized, user satisfaction had a significant positive effect on individual impact. These results are consistent with those of Hubona and Cheney [23] who found both a direct relationship between system characteristics and user performance, and a relationship mediated by user satisfaction. The results are also consistent with those of Gatian [17] and Gelderman [18] as these studies both included direct measures of individual impact.

Davis and Srinivasan [13] commented that although user satisfaction is commonly used to judge information systems success because it is a more convenient measure than performance related measures, there is also an implicit assumption that user satisfaction with an information system results in some positive change in user behavior resulting in increased effectiveness. The results of this study provide support for this assumption, however, the finding that user spreadsheet knowledge has an independent effect of similar size, and that together these factors leave 66% of the variance in individual impact unexplained, indicates that other factors also play a major role in determining individual impact. Use of user satisfaction as the sole indicator of UDA success therefore runs the risk of omitting other factors that may affect success to an equal or even greater degree.

5.5. Individual impact reflects user spreadsheet knowledge

As hypothesized, user spreadsheet knowledge had a significant positive effect on individual impact. Thus, successful use of user-developed spreadsheet applications in this study appeared to require substantial end user knowledge. This is likely to be because of the lack of separation of data and processing that is commonly found in spreadsheet applications [22] and [46]. Development of good quality UDAs should, however, reduce this dependence on the development tool knowledge of the user. Users in this study required spreadsheet knowledge for successful use because the applications were generally of low quality. Application development tool knowledge may also play an important role in the use of other kinds of UDAs and should be investigated in future research.

5.6. User spreadsheet knowledge does not influence perceived system quality

It was hypothesized that end users with more spreadsheet knowledge would perceive applications to be of lower system quality. This hypothesis was developed based on McGill's [30] study of the ability of end users to assess the quality of their applications, and justified by the assumption that end users with low levels of spreadsheet knowledge may not recognize system quality problems and hence may have inflated perceptions of quality, whereas end users with high levels of knowledge may be more critical [56]. However, this hypothesis was not supported, user spreadsheet knowledge did not influence perceived system quality.

One possible reason why this hypothesis was not supported involves the size of the applications. As previously discussed, the applications developed in this study were relatively small. It is likely that system quality problems were fairly visible in these applications so that even those users with little spreadsheet knowledge became aware of them. Reithel, Nichols, and Robinson [40] noted that the probability of errors is higher in larger spreadsheets, yet end user developers are more confident about large spreadsheets than about small spreadsheets. The size and complexity of applications developed by end users is growing [34] and [55], so a better understanding of the role of these factors in UDA success is required.

5.7. No observed direct effect of system quality on individual impact

The tested structural model included a direct influence of system quality on individual impact. Failure to observe a direct relationship in this case may reflect the correcting effect of the users' spreadsheet knowledge. Unlike compiled applications, spreadsheet applications may be easily corrected and enhanced, unless heavily protected. This is particularly true for relatively small and straightforward applications such as the ones in this study. It may be that knowledgeable users were able to overcome the defects in lower quality applications to achieve good performance on the car rental questions by making minor adjustments to the UDAs. While participants were instructed not to attempt to redesign spreadsheets they were told they could make corrections and adjustments to the spreadsheets, and did so.

6. Conclusions

The model of the relationship between spreadsheet knowledge and success which emerges from this study has helped to provide insight into the importance of spreadsheet knowledge for successful use of a spreadsheet application. As Fig. 3 shows, it enables analysis of the different ways in which user developer knowledge and user knowledge affect the success of a spreadsheet application.

In this study, spreadsheet knowledge was shown to be important in two ways. It influences the quality of the system being developed, but it also acts directly upon the individual impact of the application. While users of enterprise systems do not require knowledge of the tools with which systems are developed, successful use of user-developed spreadsheet applications appears to require sufficient knowledge to understand and, if necessary, alter the application. Thus, problems with the system quality of spreadsheet applications can be partially balanced by the spreadsheet knowledge of the user. This relationship between tool knowledge and individual impact should be explored for other kinds of end user development tools in future research.

Appendix A.

System quality and perceived system quality items

	Strongly disagree						Strongly agree
Using the spreadsheet would be easy, even after a long period of not using it	1	2	3	4	5	6	7
Errors in the spreadsheet are easy to identify	1	2	3	4	5	6	7
The spreadsheet increased my data processing capacity	1	2	3	4	5	6	7
The spreadsheet is easy to learn by new users	1	2	3	4	5	6	7
Should an error occur, the spreadsheet makes it straightforward to perform some checking in order to locate the source of error	1	2	3	4	5	6	7
The data entry sections provide the capability to easily make corrections to data	1	2	3	4	5	6	7
The same terminology is used throughout the spreadsheet	1	2	3	4	5	6	7
This spreadsheet does not contain any errors	1	2	3	4	5	6	7
The terms used in the spreadsheet are familiar to users	1	2	3	4	5	6	7
Data entry sections of the spreadsheet are organized so that the different bits of data are grouped together in a logical way	1	2	3	4	5	6	7
The data entry areas clearly show the spaces reserved to record the data	1	2	3	4	5	6	7
The format of a given piece of information is always the same, where ever it is used in the spreadsheet	1	2	3	4	5	6	7
Data is labeled so that it can be easily matched with other parts of the spreadsheet	1	2	3	4	5	6	7
The spreadsheet is broken up into separate and independent sections	1	2	3	4	5	6	7
Use of this spreadsheet would reduce the number of errors you make when choosing a rental car	1	2	3	4	5	6	7
Each section has a unique function or purpose	1	2	3	4	5	6	7
Each section includes enough information to help you understand what it is doing	1	2	3	4	5	6	7
Queries are easy to make	1	2	3	4	5	6	7
The spreadsheet provides all the information required to use the spreadsheet (this is called documentation)	1	2	3	4	5	6	7
Corrections to errors in the spreadsheet are easy to make	1	2	3	4	5	6	7

User satisfaction items

How adequately do you feel the spreadsheet meets your information processing needs when answering car rental queries?	inadequately	1 2 3 4 5 6 7	adequately
How efficient is the spreadsheet?	inefficient	1 2 3 4 5 6 7	efficient
How effective is the spreadsheet?	ineffective	1 2 3 4 5 6 7	effective
Overall, are you satisfied with the spreadsheet?	dissatisfied	1 2 3 4 5 6 7	satisfied

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Fig. 1. Hypothesized model of the effect of spreadsheet knowledge on the individual impact of a user-developed spreadsheet application.

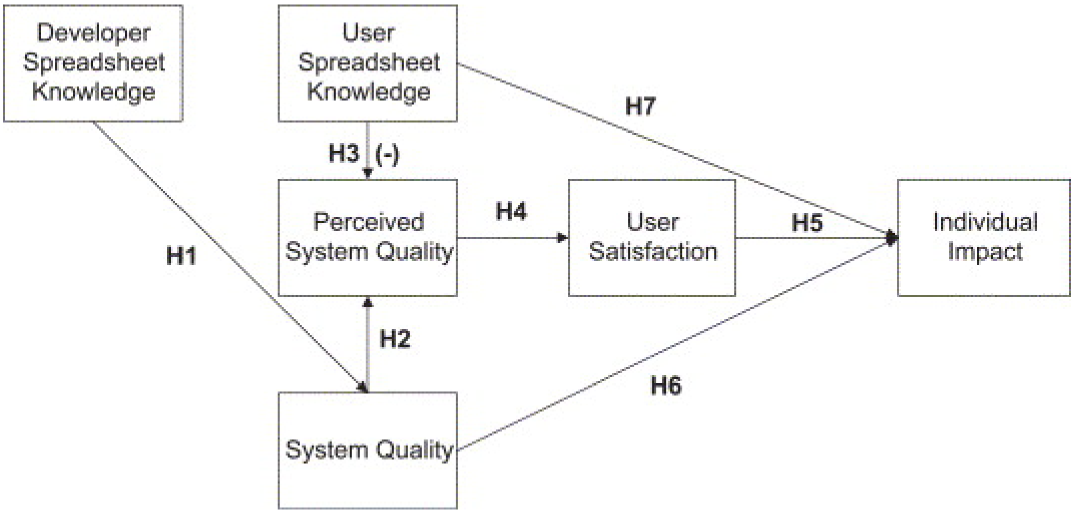

Fig. 2. Structural equation model showing the standardized path coefficient for each hypothesized path and R2 for each dependent variable.

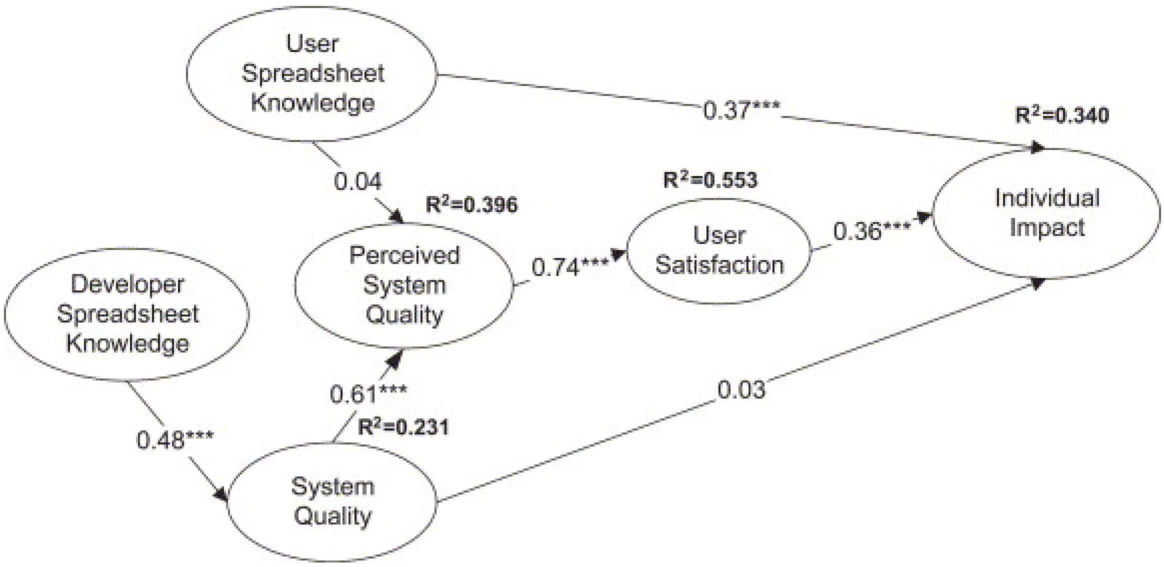

Fig. 3. Spreadsheet knowledge impact model.

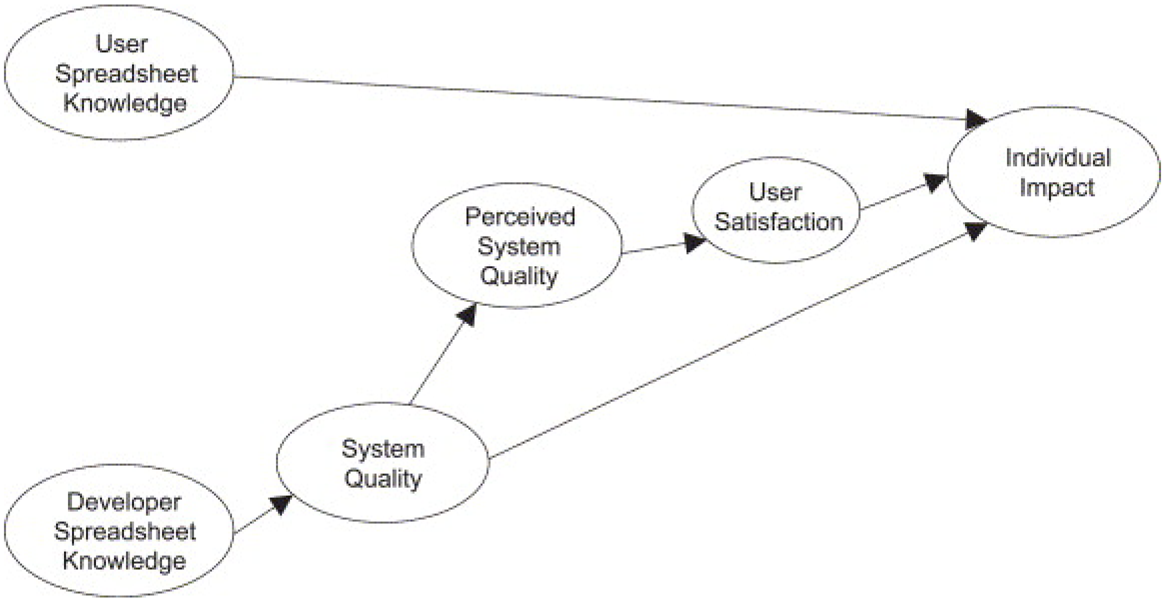

Table 1.

Measurement models

Construct[a]	Cronbach alpha	Composite reliability	Variance extracted	Mean	S.D.	Loading	Error
Composites created							
System quality	0.94	0.89	0.63	3.96	1.17	1.088	0.146
Perceived system quality	0.94	0.84	0.51	4.00	1.48	1.409	0.220
User satisfaction	0.96	0.96	0.86	3.65	2.07	2.030	0.172
Single item indicators							
Spreadsheet knowledge	0.78			12.27	4.82	1	0
Individual impact				3.49	3.22	1	0

[a] $n = 157$.

Table 2. Goodness of fit measures, model coefficients, standard errors, and *t* values for the model

Path from	To	Estimate	Standard error	*t* Value
Developer spreadsheet knowledge	System quality	0.108	0.017	6.378***
System quality	Perceived system quality	0.703	0.092	7.655***
User spreadsheet knowledge	Perceived system quality	0.010	0.019	0.518
Perceived system quality	User satisfaction	0.711	0.058	12.313***
User satisfaction	Individual impact	1.039	0.223	4.662***
System quality	Individual impact	0.090	0.274	0.328
User spreadsheet knowledge	Individual impact	0.266	0.052	5.131***
Goodness of fit measures				
Chi-square (χ^2)		5.23, $df = 7$, $p = 0.632$		
χ^2/df		0.747		
GFI		0.989		
AGFI		0.967		
RMSEA		0.000		
TLI		1.008		

$^{***}p < 0.001$.

Table 3. Standardized total effects on dependent variables estimated for the model

	Developer spreadsheet knowledge	User spreadsheet knowledge	System quality	Perceived system quality	User satisfaction
System quality	0.481*				
Perceived system quality	0.294**	0.039	0.612**		
User satisfaction	0.219**	0.029	0.456**	0.744*	
Individual impact	0.092*	0.381**	0.191*	0.265*	0.357*

* $p < 0.05$ (two-tailed).
** $p < 0.01$ (two-tailed).