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QUALITY ASPECTS AND METRICS IN M-LEARNING INFORMATION SYSTEMS

Abstract: *The development of modern information systems can not be imagined without the incorporation of quality aspects in this process. Information systems can be viewed and evaluated from the technical point of view, as software products, and from the user point of view, as systems that provide a particular service. M-learning information systems are the systems that enable education process on mobile devices, and they have a number of specific characteristics compared to the information systems for desktop computers. This paper presents different aspects of the quality of m-learning information systems. Also, a new model and metrics for the evaluation of the quality of m-learning solution are proposed, which are based on an objective assessment of the acquired knowledge, but also on a subjective user assessment i.e. client satisfaction. This model was used for the evaluation of a new web-based m-learning solution and experimental learning realized on this system.*

Keywords: *mobile device, mobile learning, quality metrics, mobile web*

1. INTRODUCTION

Intensive development of information-communication technologies, especially wireless communications and mobile telephony in the last two decades, enabled the emergence of new form of education - mobile learning (m-learning), which is based on the use of mobile devices in all forms and aspects of education.

One of the key advantages of mobile learning is the widespread availability of mobile devices, primarily mobile and smart phones, which today represent the most widespread technological device (according to [1], there are more than 5.9 billion mobile subscriptions i.e. the global penetration is more than 87%). Another important advantage is that education system is based on the existing technological infrastructure (mobile network and the Internet), so that the introducing costs are relatively low. Also, the learning materials are in digital form, so it is relatively easy to adapt already developed e-learning content to mobile devices, taking into account all its characteristics.

Information systems for m-learning must be fully adapted to mobile devices, and developed in accordance with their advantages and disadvantages i.e. usually it is not possible to use already developed e-learning systems without adaptation. In the process of system development it is necessary to comply with all relevant standards for software development and information systems design, and take care of all quality aspects of the developed solution.

In this paper, a new system for m-learning, based on the mobile Web, and

key quality aspects and metrics for the m-learning information systems are presented. Also, novel quality model, based on the combination of quality objective individual assessments, is presented. Finally, the quality model was tested for the assessment of proposed information system and performed experimental training.

2. QUALITY ASPECTS

The quality of m-learning information systems can be analyzed and evaluated from two aspects:

1. From the technical point of view, treating the system as a software product, i.e. the compliance with the relevant technical standards,

2. From the user point of view i.e. client satisfaction, treating education as a service and learners as clients [2].

Although there are several models for defining software quality, best known and the most often used is ISO/IEC 9126 standard, defined by International Standard Organization (ISO) and International Electro-technical Commission (IEC). This standard applies to the quality of software engineering products, especially from the technical point of view [3], and it consists of four parts, of which the most interesting for this paper are first part, related to the quality model and the fourth part, which is related to quality in use. By this standard, the software engineering product quality is decomposed into seven characteristics, as shown in Figure 1 [4].

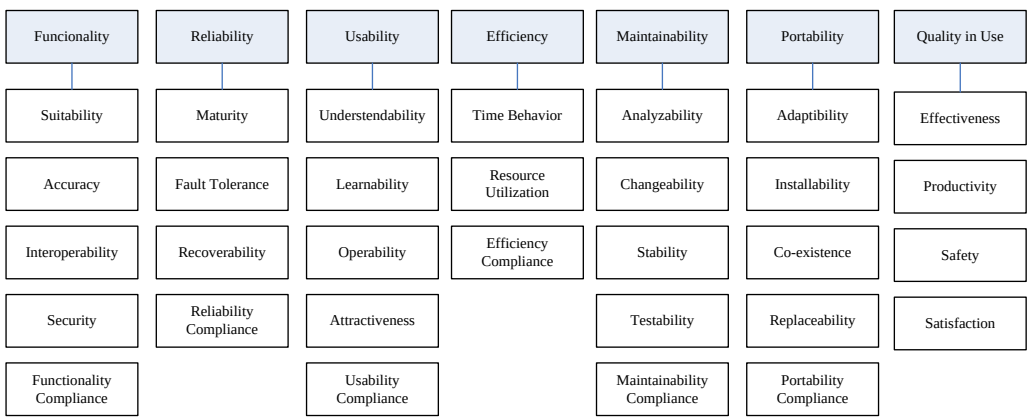

Figure 1. ISO/IEC 9126 quality characteristics and sub-characteristics

Key characteristics (Functionality, Reliability, Usability, Efficiency, Maintainability, Portability and Quality in Use) are further divided into sub-characteristics, as can be seen in Figure 1. This standard also, for each of these sub-characteristics, defines internal (which can be measured without having to operate the system) and external metrics, which is measured during testing or use of the system. Using this standard, Gafni ([4], [5]) proposed to extend these metrics with the specific or especially important elements for mobile information systems, such as display load, cleanup device memory, speed of user location update, ease of entering input, etc.

Boja and Batagan [6] proposed a quality model for m-learning applications, which consists of several indicators (sorted by identified level of importance), such as loading time, path length to resources searched, homogeneity degree of data input process, information required user

level, continuity of human-application interaction, complexity, symmetry and homogeneity of user components, etc. Also, Parsons and Ryu [3] analyzed technical quality aspects and suggested a framework for assessing the quality of mobile learning. As previous, these models treat only technical quality of the information system.

Second approach as the most important quality measure takes subjective user assessment. Well known methods for service quality assessment, such as SERVQUAL or SERVPERF, which are based on a subjective assessment of customer satisfaction, can not be directly applied to m-learning, which falls into the category of electronic services and has a number of specific properties i.e. a number of categories from original SERVQUAL model can not be applied. Therefore, a number of quality models of electronic and web services that take into account the specificity of this form is developed [7]. For example, Loiacono et al. [8] suggest WebQual, a scale for evaluating web sites according to 12 dimensions: informational fit to task, interaction, trust, response time, design, intuitiveness, visual appeal, innovativeness, flow-emotional appeal, integrated communications, business processes and substitutability.

Barnes and Vidgen [9] developed a completely different scale, but with the same name - WebQual. This scale is primarily related to e-commerce, and was based on five factors: usability, design, information, trust and empathy. Yoo and Donthu [10] for measuring site quality on four dimensions (ease of use, aesthetic design, processing speed and security) proposed SITE-QUAL, nine-item quality scale.

For assessing electronic service quality, Parasuraman et al. [7], analyzing as many as 11 dimensions of quality of electronic services, finally developed ES-QUAL model based on following four dimensions:

- Efficiency - ease and speed of accessing and using the site,
- Fulfillment - the extent to which the site's promises are fulfilled,
- System availability – the correct technical functioning of the site,
- Privacy - the degree to which the site is safe and protects customer information.

with a total of 22 questions (as SERVQUAL) in all four categories. The research showed that the most critical and equally important dimensions were efficiency and fulfillment, and then system availability, while privacy was the least important. It should be noted that most of the presented models were used primarily for assessing the quality of e-commerce solutions [7].

For electronic service providers, some internal, primarily technical quality measures such as server response time or the average number of user clicks on the site are relatively easily available, but not enough to really assess the service quality, without taking into account the client perception [11].

Based on a thorough literature review in the field of electronic service quality, Fassnacht and Koese [11] recognized the following aspects of service quality that usually occur in the analyzed models: ease of use, quality of appearance/layout, information quality, privacy/security, reliability, speed/responsiveness and content, with privacy and security considered as the least relevant and least important quality measure. In their research, they have proposed a conceptual hierarchical model of electronic service quality, which consists of three main dimensions and nine sub-dimensions, as shown in Figure 2.

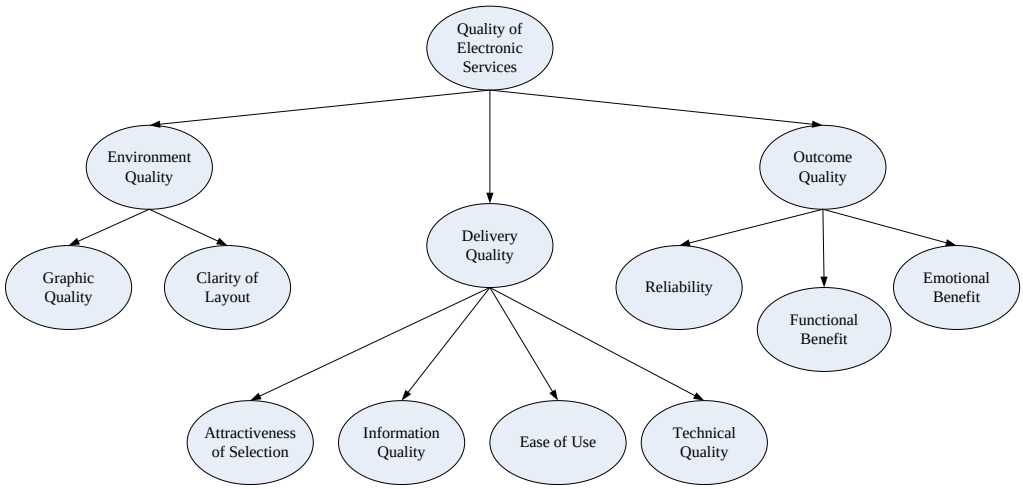

Figure 2. Model of quality of electronic services

In traditional services, environment is related to the physical environment in which the service is provided, delivery is a process of interaction between staff and clients and the outcome is a benefit for the client after completion of the service. Rust and Kannan [12] showed that these three dimensions can be applied to electronic services: the appearance of the user interface is a Web site service environment, the delivery of service is related to the interaction of the client with the user interface while performing services, and service outcome, as well as in traditional system, is the benefit of the client after the service is performed.

Tate et al. [13] pointed out that numerous studies showed that the user perception on service quality in higher education is very similar to the perception in the business sector. The authors considered E-Qual (WebQual (4.0)) instrument for assessing the quality of web solutions, in which the emphasis is on usability, not on the technical quality of the site. The main categories in this model were: usability (which includes aspects such as navigation, layout and general ease of use), information quality (which encompasses accuracy, timeliness, relevance, granularity and general believability of information) and the service interaction quality (security, trust, personalization, access, etc.). The authors have proposed the extension of the above E-Qual model with a new category: Quality and security of transactions. Verification of this solution showed that the most important dimensions were quality of content and ease of use.

In the literature it is hard to find relevant examples of specific quality models of the systems for m-learning, based on user satisfaction.

3. QUALITY MODEL

In this paper, user satisfaction is adopted as a major factor and main measure for quality assessment of developed solution, because technically perfect product does not guarantee a high quality evaluation by the user (of course, it is important that in the development phase all relevant technical aspects and standards should be taken into account). In addition, quality model for m-learning information system should take into account all the specifics of mobile devices and mobile access. For example, as opposed to electronic services based on Web access

from a PC, for mobile solutions visual attractiveness of the design is not very important. In this paper, as a key quality aspects of m-learning information system are considered:

- Ease of use,
- Simple and clear design,
- Fast and intuitive navigation,
- Availability, both in terms of time and place,
- Fast and stable access to the course,
- Quality of learning content.

All these aspects were taken into account when forming the questionnaire used for user evaluation of developed system during experiment.

Apart from the perspective of users, the quality of the education system can be viewed from the perspective of education providers. Key quality objectives, considered in this paper, and their relationships with the two perspectives are presented in Figure 3.

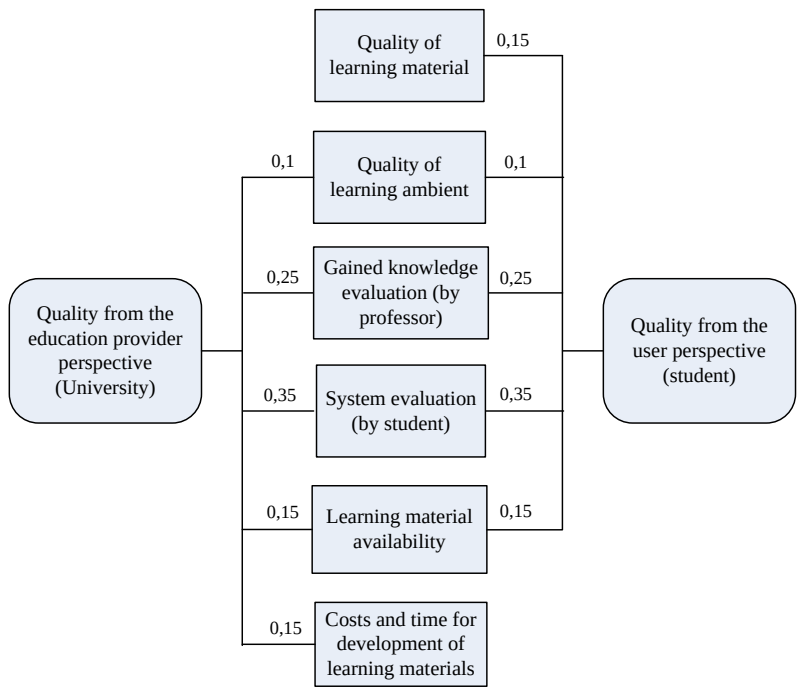

Figure 3. Quality model and key perspectives

Based on these aspects it is possible to define a single quality grade, based on the evaluations of single aspects and weight (influence) factors:

$$Q = \sum_{i=1}^{5} w_i \cdot v_i \qquad (1)$$

where w_i - is weight factor of i-th quality aspect, v_i - is evaluation (grade) of the i-th quality aspect, with basic condition $w_1 + w_2 + w_3 + w_4 + w_5 = 1$. Figure 3 shows the adopted values of weight factors for both perspectives. The greatest impact on the quality has the user evaluation of the system (subjective satisfaction), and mark given by professor (as a measure of successfully gained knowledge).

The adopted quality objectives and aspects are influenced by a number quality factors, of which most notably are:

- Software quality,
- Quality of mobile device,
- Quality of the access network,
- Level of learning material personalization,
- Teaching staff competence, etc.

The relations between analysed quality factors and quality objectives, with the strength of the influence (strong or weak) of each relationship, are shown in Figure 4.

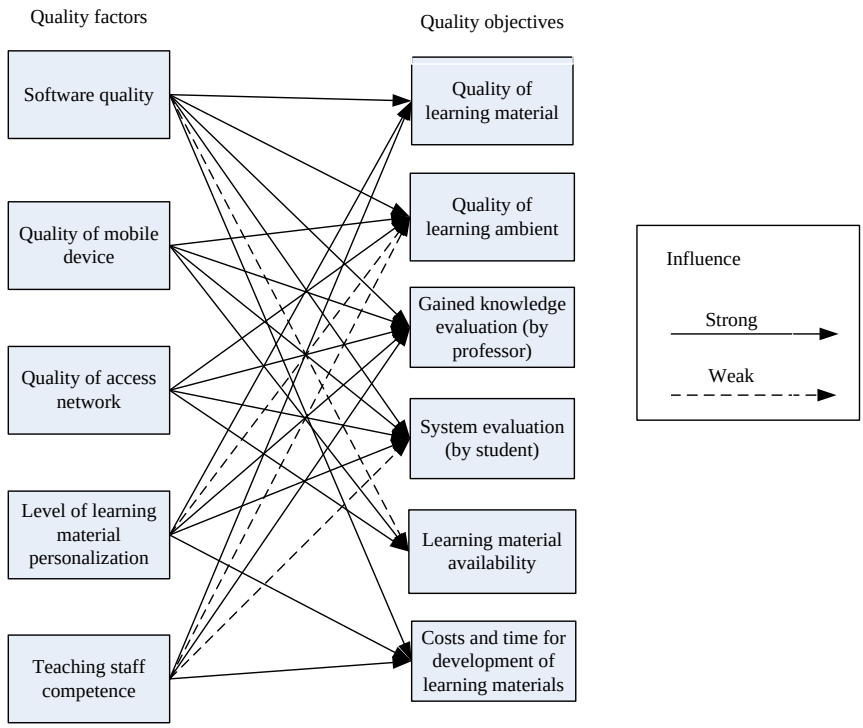

Figure 4. The relationship between quality factors and objectives

The more precise nature of these relationships was not investigated in details, but is left for further research.

4. M-LEARNING INFORMATION SYSTEM

The proposed quality model was tested on the information system for m-learning, developed at the Faculty of Economics, University of Kragujevac and experimental training realized at the same University. Information system was realized as a mobile web application, developed using XHTML MP, PHP and MySQL [14]. The solution was personalized system, i.e. the adaptation of the content was done according to the characteristics of mobile devices (WURFL mobile device database was used to identify device characteristics) and the user learning style (Felder-Silverman learning style model and defined adaptation rules were used). In addition to the access to the learning material, the system enabled information and news delivery, self-testing of acquired knowledge, contacts with teachers, etc. Some of the forms of m-learning web application are presented in figure 5.

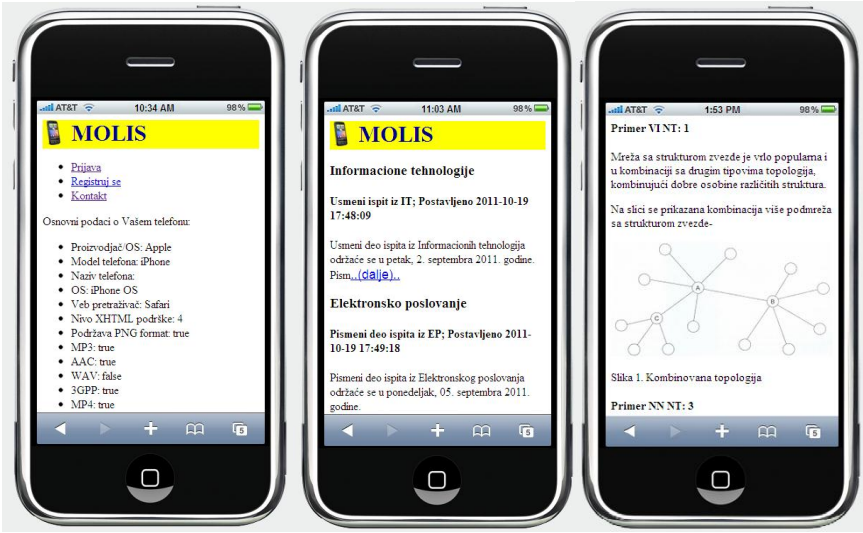

Figure 5. M-learning application

More details on developed m-learning information system can be found in [15] and [14].

5. RESULTS

Experimental training was carried out with the students of undergraduate studies at Faculty of Economics, University of Kragujevac, during summer semester of year 2010/11, at Information Technologies course. In total, 41 students participated in the experiment. At the end of the learning period, all students filled out a questionnaire in which they evaluated their experience with the proposed system for m-learning.

Based on the proposed quality model and metrics and the results and evaluations by questionnaire of all tested students, the single quality grades (per student) from the perspective of education provider (University) and user (students) were determined (using Eq. (1)) and these results are shown in Figure 6.

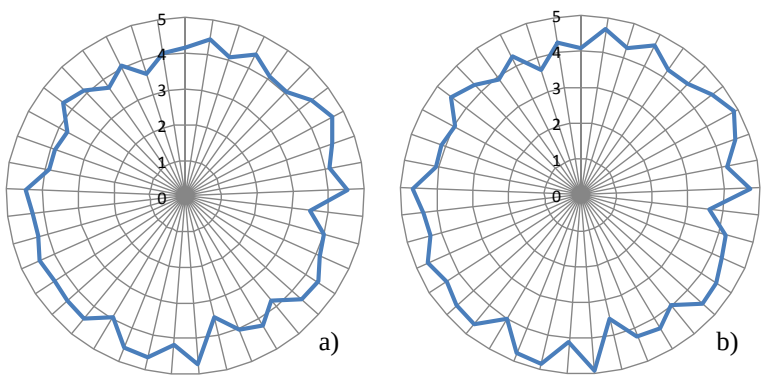

Figure 6. Single quality grades per student from the perspective of a) education provider, b) student

Total grades of key quality aspects (calculated as averages of appropriate student grades), from education provider and user perspectives, presented in Figures 7 and 8, shows good evaluation results on all analysed aspects.

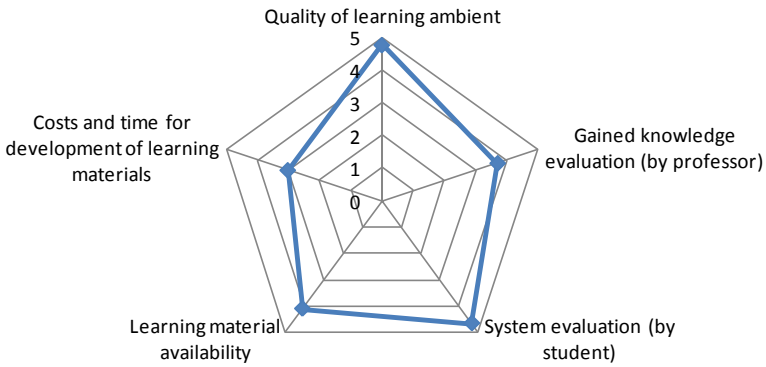

Figure 7. Single quality grades for quality aspects from the perspective of education provider

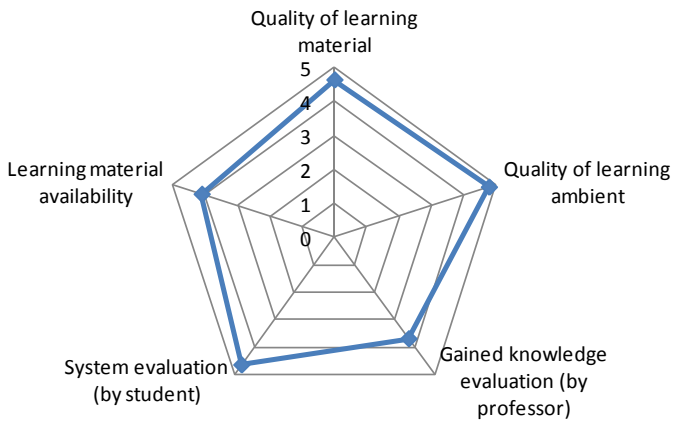

Figure 8. Single quality grades for quality aspects from the perspective of student

Finally, single overall quality grade was determined for both perspectives, and its value and standard deviation are given in Table 1.

Table 1. Overall quality grade and standard deviation, from education provider and user perspectives

Overall quality grade	*Mean*	*St. dev.*
Education provider perspective	4.08	0.26
User perspective	4.24	0.28

It is clear that from both perspectives the m-learning information system and training performed were very highly graded.

6. CONCLUSION

In this paper, different approaches of quality assessment of information systems for mobile learning were disscussed, primarily from the aspects of technical software quality and customer satisfaction. Numerous quality models developed so far are presented and a new model, based on a

combined assessment of both subjective user satisfaction, and objective knowledge gained by the use of this system of education is proposed.

The originally developed personalized m-learning information system, based on mobile Web, on which experimental training was conducted, is also presented. The results show that students, participants in the experiment, highly rated the proposed m-learning solution on all analysed quality aspects.

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