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A structured methodology for assessing and improving e-services in digital cities

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ABSTRACT

Many cities all over the world are making large investments for the construction of big network infrastructures, in order to offer to local public organizations, businesses and citizens high speed connectivity, and on top of them useful e-services, aiming to achieve various social and economic objectives. The value generated from these costly 'digital city' investments is actually the value provided to the citizens and businesses by the e-services that will be developed and run on these network infrastructures. This paper proposes and validates a structured methodology for assessing and improving e-services developed in digital cities. The proposed methodology assesses the various types of value generated by an e-service, and also the relations among them, allowing a more structured evaluation, a deeper understanding of the value generation process and also identification and prioritization of the improvements that should be made in the e-service with the usually scarce resources in municipalities. This methodology is applied for the evaluation of an e-learning service developed in the Greek city of Karlovassi for young citizens, and also for the prioritization of the necessary improvements in it. The above application provided positive and encouraging evidence concerning the validity, usefulness and applicability of the proposed method.

1. Introduction

Information and communication technologies (ICT) have a great potential to facilitate rapid accumulation and dissemination of information and also group interaction, communication and collaboration, so they increasingly become of critical importance for the professional and social life of individuals and for the development of businesses and regions. For this reason numerous projects have been implemented or are in progress for the development of "digital cities", aiming to construct electronic highways and spaces where local citizens, businesses and public organizations can interact and share information and knowledge (Ishida, 2002; Tanabe et al., 2002; Gillett et al., 2004; Tapia et al., 2006; Ortiz and Tapia, 2008a,b). In this direction many cities are constructing extensive network infrastructures, which offer to local public organizations, businesses and homes high speed connectivity, and on top of them are developing various kinds of e-services, which aim at both economic objectives (such as enhanced competitiveness and growth of local businesses) and social objectives (such as higher quality of life, better services to various groups, social networking and inclusion, promoting civic engagement, environmental protection, overcoming the 'digital divide', etc.). These e-services are of vital importance for the exploitation of the costly 'digital city' network infrastructures; without useful and widely used e-services these infrastructures do not offer any value.

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Finally, the value generated from the big 'digital city' investments is actually the value provided to the citizens and businesses by the e-services developed and running on these network infrastructures. However, it has been remarked that in general despite the large number of e-services provided by numerous private enterprises and public organizations in many countries, their usage has been much lower than expectations, while their users perceive significant quality problems of them (Parasuraman et al., 2005; European Commission, 2008; Sumak et al., 2009). Therefore it is of critical importance to evaluate the e-services developed as part of 'digital city' projects in a way that allows a good understanding of their strengths and weaknesses, the different types of value they generate and their value generation processes, and also to identify the main improvements that should be made in order to overcome their weaknesses and increase their quality and value.

However, this is not an easy task. The provision of an e-service is usually characterized by high complexity, as it necessitates combination of many different elements, such as technological infrastructures (hardware, software and networks), other 'traditional' or electronic services, various types of goods, human resources and organizational structures (Zwass, 1996). Khalifa and Liu (2003) argue that the factors which should be taken into account for the evaluation of the quality of an e-service are multiple, not restricted to its main characteristics, but also including customer or end-user satisfaction, acceptance/adoption and support before, during and after the transaction. The evaluation therefore of an e-service is a complicated, multidimensional process, which should combine aspects from various and, sometimes, heterogeneous fields; it should include the assessment of the infrastructures and systems that support the e-service, the human resources participating in its production and provision, and also the service itself: how user-friendly and useful it is, how much it assists users for performing various tasks and achieving various objectives and to what extend it influences their future behavior. For this purpose, previous research has developed various e-services evaluation frameworks, which provide useful evaluation dimensions and measures (criteria) (e.g. Wolfinbarger and Gilly, 2003; Rowley, 2006; Halaris et al., 2007; Sumak et al., 2009 – an extensive review of them is provided in the following Section 2). Most of them focus on the quality assessment of a particular kind of e-services (e.g. informational web sites, e-shops, e-learning, e-government), while very few are generic (i.e. aim at the evaluation of e-services in general). However, in order to evaluate 'real-life' e-services further elaboration, adaptation or even synthesis of these frameworks is required. Also, by examining these frameworks in more detail we remark that most of them propose heterogeneous sets of evaluation measures, which usually consist of several more homogeneous subsets, each of them assessing a particular quality aspect of the e-service (that corresponds to a type of generated value), such as the quality of a capability or resource provided to the users, or to what extent it assists users in performing a particular task or achieving a particular objective, or even to what extent it influences their future behavior. Between these aspects there are usually relations: some of these aspects are 'independent' variables under the direct control of the e-service provider (e.g. the quality of the various capabilities and resources provided to the users), while some other aspects are 'dependent' variables-outcomes, which are not under the direct control of the e-service provider (e.g. the extent of assisting users to perform a particular task or achieve a particular objective), but to some extent depend on (usually are caused by) the independent ones.

Therefore in order to make a more complete and structured evaluation of an e-service, assess the various types of value it generates, obtain a deeper understanding of the value generation process and also identify and prioritize the improvements that should be made in it with the usually scarce resources available, it is necessary to adopt the following approach: (i) formulate groups of evaluation measures corresponding to the different types of value generated by the e-service, (ii) using them assess the level of each type of value generated based on users' ratings, and (iii) estimate the relations between these types of value establishing a 'value flow' model. In this direction the present paper proposes and validates a structured methodology that follows the above approach for assessing and improving e-services developed in digital cities context. It is based on the assessment of five kinds of evaluation measures, which assess the quality of the resources and capabilities provided by the e-service to its users (efficiency), its context, its usage, the assistance it provides to users in performing various tasks and achieving various objectives (effectiveness) and its impact on users' future behavior, and also on the estimation of the relations among them. Such a methodology is very useful in a digital city context, in which various types of innovative e-services (not belonging to the 'usual' ones, e.g. information portals or e-shops) are developed, providing many different types of value to wide and heterogeneous users groups. The proposed methodology has been applied for the evaluation of an e-learning service developed in the Greek city of Karlovassi for young citizens, and for the identification and prioritization of the necessary improvements of it.

The paper is structured as follows: this introduction is followed by Section 2 outlining the background of this research, which consists of the main conclusions and frameworks from previous research on information systems (IS) evaluation, e-services evaluation and e-learning evaluation. Then in Section 3 is described the proposed e-services assessment and improvement methodology, while in Section 4 the abovementioned application of it is presented and in Section 5 its results are presented and discussed. Finally Section 6 summarizes the conclusions and proposes future research directions.

2. Background

2.1. Information systems evaluation

Extensive research has been conducted for more than two decades concerning information systems (IS) evaluation, aiming to formulate methodologies for identifying the full range of positive and negative impacts of an IS (Hirschheim and

Smithson, 1988; Smithson and Hirscheim, 1998; Farbey et al., 1999; Irani, 2002; Irani et al., 2006; Gunasekaran et al., 2006). From this research it has been concluded that IS evaluation is highly complex, because the benefits and in general the value created by most categories of IS are multidimensional and complex, both tangible and intangible, financial and non-financial; for this reason it is difficult to decide "what to measure" for the evaluation and "how". Also, different categories of IS have different objectives and produce different types of benefits and value, so they require different kinds of evaluation methods and measurements. Farbey et al. (1995) classify IS into eight categories based on the method required for evaluating them (mandatory IS, automation IS, direct value added IS, management information and decision support systems (MIS–DSS), infrastructure IS, inter-organizational IS, strategic IS and business transformation IS) and propose a different evaluation approach for each of them. Smithson and Hirscheim (1998) classify the existing IS evaluation methods into three basic categories. The first category are the 'efficiency-oriented' methods, which have been influenced mainly by engineering sciences and evaluate the performance or quality of an IS with respect to some predefined technical and functional specifications, being focused on answering the question 'is it doing things right?'. The second category consists of 'effectiveness-oriented' methods, which have been influenced mainly by management science approaches and evaluate how much an IS supports the execution of business-level tasks or the achievement of business-level objectives, being focused on answering the question 'is it doing the right things?'. The third category consists of 'understanding-oriented' approaches, which aim at obtaining a deeper understanding of the mechanisms of value generation by IS and their association with the organizational context.

Another research stream focuses on 'user acceptance' as the main measure of IS value and aims to identify the characteristics and factors affecting the attitude towards using an IS, the intention to use it and finally the extent of its actual usage, all three being regarded as the basic measures of user acceptance. It is based on the Technology Acceptance Model (TAM) and its extensions (Davis, 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2003). According to the initial TAM the attitude towards using an IS, which finally determines the intention to use it and its actual use, is determined mainly by two characteristics of it: its perceived 'ease of use' (=the degree to which potential users believe that using it would require minimal effort) and its perceived 'usefulness' (=the degree to which potential users believe that using it will enhance their job performance) (Davis, 1989); each of these two factors can be elaborated into a detailed set of variables for each particular type of IS we want to study, and can also be affected by various 'external factors' (e.g. organizational or individual). Based on these foundations extensive research has been conducted aiming to understand better and predict user acceptance of IS in general or of particular types of IS; a review and meta-analysis of this research stream is provided by Schepers and Wetzels (2007). Subsequently, through combination of factors from several technology acceptance theories and models (including the TAM) a 'Unified Theory of Acceptance and Use of Technology' (UTAUT) has been developed (Venkatesh et al., 2003); it theorizes that four basic constructs are the main direct determinants of technology acceptance and use: performance expectancy, effort expectancy, social influence and facilitating conditions. Also, considerable research in this area has been based on the IS success models, such as the one developed by DeLone and McLean (1992, 2003): its basic constructs are information quality, system quality and service quality, which affect user satisfaction and also the actual use of the IS; finally these two constructs determine the impact of the IS at the individual and organizational level. Another smaller research stream has focused on the quality of the software, which is; it has been mainly based on the ISO/IEC 9126 Software Quality Model (2001), which defines the following six basic software quality dimensions: functionality, reliability, usability, efficiency, maintainability and portability.

The above basic frameworks and conclusions from the IS evaluation research have been used as foundations of the e-services and e-learning evaluation research reviewed in the following Sections 2.2 and 2.3, respectively.

2.2. e-Services evaluation

The increasing investment for the development and provision of e-services by numerous private enterprises and public organizations, which has resulted in a wide availability of various kinds of e-services in many countries, and at the same time the low level of usage of them in comparison with expectations and the quality problems reported by the users (Parasuraman et al., 2005; European Commission, 2008; Sumak et al., 2009), has driven considerable research in the area of e-service evaluation and quality. This research has been based on conclusions and frameworks from the general IS evaluation research (such as the TAM, the IS success models, etc.) and also on quality models developed for the 'traditional' services. The most widely used of them has been the SERVQUAL (Parasuraman et al., 1988; Berry et al., 1990), which is a model for service quality measurement and management consisting of 22 service quality measures organized in five dimensions: tangibles (appearance of physical facilities, equipment, personnel and communication materials), reliability (ability to perform the promised service dependable and accurately), responsiveness (willingness to help customers and provide prompt service), assurance (knowledge and courtesy of employees and ability to convey trust and confidence) and empathy (provision of caring, individualized attention to customers). From this research have been developed frameworks for assessing the quality of some particular highly used kinds of e-services (e.g. informational web sites, e-shops, e-learning, e-government), or of e-services in general, which provide appropriate useful evaluation dimensions and measures (criteria); in the following we are going to outline the conclusions of some representative studies of this research stream, while a more detailed review of it is provided by Sumak et al. (2009).

Loiacono et al. (2000), using as their basic theoretical foundations the Theory of Reasoned Action (Fishbein and Ajzen, 1975) and the TAM (Davis, 1989), developed the WebQual scale for measuring web site quality, which consists of 36 items

organized in the following 12 core dimensions: informational fit-to-task, tailored communications, trust, response time, ease of understanding, intuitive operations, visual appeal, innovativeness, emotional appeal, consistent image, on-line completeness and relative advantage. Aladwani and Palviab (2002) developed an instrument for capturing the main web site quality characteristics, which includes 25 items forming four core factors: content quality, specific content, appearance and technical adequacy. Iwaarden et al. (2003) expand and adapt the abovementioned SERVQUAL quality model in order to be used for web sites quality evaluation; the resulting model includes five quality dimensions corresponding to the ones of the initial SERVQUAL model, with their meaning adapted to the specificities of the web sites: tangibles (appearance of the web site, navigation, search options and structure), reliability (ability to judge the trustworthiness of the offered service and the organization performing the service), responsiveness (willingness to help customers and provide prompt service), assurance (ability of the web site to convey trust and confidence in the organization behind it with respect to security and privacy) and empathy (appropriate user recognition and customization). Ivory and Megraw (2005) by examining the characteristics of highly rated web sites identified an extensive set of measures for assessing web site quality; it consists of 157 page- and site-level items measuring five quality aspects: information, navigation, graphic design, page performance and overall site architecture.

Another group of studies have dealt with the quality assessment of e-business web sites. Barnes and Vidgen (2002) drawing on previous work from the areas of web site usability, information quality, and service interaction quality constructed a index for measuring the quality of an organization's e-commerce offering, which is based on five factors: usability, design, information, trust and empathy. Wolfinbarger and Gilly (2003) developed a 14-item scale for measuring e-retailers' quality, which form four factors: web site design (involving attributes associated with design, personalization and product selection), reliability/fulfillment (involving accurate representation of the product, on-time and accurate delivery of orders), privacy/security (concerning trust to the site) and customer service (interest in solving problems, willingness of personnel to help, and prompt answers to inquiries). Parasuraman et al. (2005) constructed, refined and tested the multiple-item scale E-S-QUAL for measuring the service quality delivered by web sites in which customers shop on-line. The basic form of it is a 22-item scale of four dimensions: efficiency, fulfillment, system availability, and privacy; also, in the same study another scale has been developed, titled E-RecS-QUAL, salient only to customers having nonroutine encounters with the sites, which contains 11 items in three dimensions: responsiveness, compensation, and contact. Halaris et al. (2007) focused on the quality of e-government services; through a comprehensive review of previous literature in several relevant areas (quality of traditional public services, e-services quality, quality of e-government services) they synthesized a model for assessing quality of e-government services consisting of four layers: back office performance layer (including factors from quality models for traditional government services), site technical performance layer (with factors concerning various aspects of the technical performance of the web site, such as reliability, security, etc.), site quality layer (with factors associated with the interface and usability) and customer's overall satisfaction layer. Behkamal et al. (2009) developed a quality framework for B2B e-commerce services by customizing the abovementioned ISO/IEC 9126 Software Quality Model; it consists of six quality dimensions, each of them including a number of quality factors: functionality (suitability, accuracy, interoperability, security, traceability), reliability (maturity, fault tolerance, recoverability, availability), usability (understandability, learnability, operability, attractiveness, customizability, navigability), efficiency (time behavior, resource utilization), maintainability (analyzability, changeability, stability, testability) and portability (adaptability, install ability, co-existence, replace ability).

However, much smaller is the number of studies that attempted to develop more generic frameworks for assessing quality of e-services in general. Rowley (2006) based on an analysis of the e-service literature synthesized an e-services quality assessment framework, which includes the following factors: site features, security, communication, reliability, customer support, responsiveness, information, accessibility, delivery and personalization. Fassnacht and Koese (2006) building on previous e-services research and findings from a qualitative study developed a broadly applicable hierarchical quality model for e-services, which consists of three dimensions and nine sub-dimensions: environment quality (graphic quality, clarity of layout), delivery quality (attractiveness of selection, information quality, ease of use, technical quality) and outcome quality (reliability, functional benefit, emotional benefit).

2.3. e-Learning evaluation

Since, as mentioned in the introduction, the application of the proposed methodology for assessing and improving e-services described in this paper concerns an e-learning service, in this section we are going to focus on previous research about e-learning evaluation. Considerable research has been conducted in this area, which has resulted in various e-learning evaluation directions and frameworks; in the following we are going to outline the conclusions of some representative studies of this research stream. Jackson (1998) suggests that the evaluation of e-learning should be based on the initial objectives, the implementation and the outcomes of it, and should also take into account its context (e.g. previous knowledge, attitudes and conceptions of the e-learners); he also provides a systematic way for the evaluation of e-learning outcomes based on the 'Structure of the Observed Learning Outcome' (SOLO) taxonomy developed by Biggs and Collins (1982). Oliver and Conole (1998) structure e-learning evaluation into the following six stages and provide systematic guidance for each of them: identification of stakeholders, formulation of questions to each group of stakeholders, selection of a research approach (quantitative or qualitative), selection of data capture techniques, selection of data analysis techniques and choice of presentation format. Garrison and Anderson (2003) proposes an e-learning evaluation framework, which includes seven stages: determination of strategic intent of the e-learning program, examination of the courses' content, examination of the design

of the interfaces, identification of amount of interactivity supported, evaluation of student assessment methods, measurement of the degree of student support and evaluation of outcomes. Wang (2003) developed an instrument for evaluating e-learning from the learners' perspective, which includes 17 items forming four factors: learner interface, learning community, content and personalization. Some other studies focus on particular aspects of e-learning, for instance Douglas and Van Der Vyver (2004) deal with the effectiveness of e-learning course materials, while Arbaugh and Fich (2007) analyze participants' interaction in on-line learning environments. Based on the IS success model of DeLone and McLean (2003) and Wang et al. (2008) developed and validated a multidimensional model for assessing e-learning systems success (ELSS) in an organizational context from the perspective of the employee (e-learner); it includes 34 items forming the following six dimensions (all adapted to the specificities of e-learning): system quality, information quality, service quality, use, user satisfaction and net benefits. Ozkan and Koseler (2009) developed the 'hexagonal e-learning assessment model' (HELAM) for assessing e-learning in the higher education context, which includes six evaluation dimensions: system quality, service quality, content quality, learner perspective, instructor attitudes, and supportive issues.

Interesting from the e-learning evaluation viewpoint is also the research work that has been conducted in the area of e-learning quality. Lorenzo and Moore (2002) proposed the following basic quality determinants of on-line education, which they call the 'Five Pillars of Quality Online Education': learning effectiveness, student satisfaction, faculty satisfaction, cost effectiveness and access. Ehlers (2004, 2005) argues that achieving quality in e-learning should be viewed as a co-production process between the learning environment and the learner, and identifies seven basic fields of e-learning quality from the e-learners' viewpoint: tutor support, cooperation and communication in the e-course, technology, costs-expectations-value relation, information transparency concerning the e-course and its provider, e-course structure and didactics. Euler and Seufert (2006) following a holistic approach to e-learning quality propose six quality dimensions: program strategy, pedagogy, economics, organization, technology and culture. Marques et al. (2008), review a number of e-learning quality frameworks, such the Open eQuality Learning Standards, SEEQUEEL – Sustainable Environment for the Evaluation of Quality in eLearning – Core Quality Framework, Inno-elearning, MECA-ODL, and Quality On the Line; also, by combining elements of them they synthesized the e-QUAL model for the evaluation of e-learning quality, which consists of the following four evaluation areas comprising 16 items in total: Learning Contents, Learning Management System, Processes and Results.

2.4. Conclusion

From the review of previous literature on e-services evaluation it can be concluded that various e-services evaluation and quality frameworks have been developed, based mainly on frameworks and conclusions from the general IS evaluation research and the 'traditional' services quality research, providing useful evaluation dimensions and measures (criteria). Most of them focus on the quality assessment of a particular kind of e-services (e.g. informational web sites, e-shops, e-learning, e-government), while very few are generic (i.e. aim at the evaluation of e-services in general). It should be noted that between them there are some similarities (e.g. common elements), but also important differences as well (e.g. in scope, focus or elements). Therefore for the evaluation of 'real-life' e-services further elaboration, adaptation or even synthesis of these frameworks is required, e.g. combination of elements (evaluation dimensions and/or measures (criteria)) from several frameworks, adaptation of them to the particular objectives, characteristics, resources, capabilities and context of the evaluated e-service, further elaboration of them, etc. Another conclusion from examining these frameworks is that most of them propose heterogeneous sets of evaluation measures of various types, which include more homogeneous subsets, each of them assessing a particular quality aspect of the e-service, such as the quality of a capability or resource provided to the users, or the extent of achieving a particular outcome (e.g. to what extent it assists users in performing a particular task or achieving a particular objective, offers them fun and enjoyment, or influences their future behavior). Each of these quality aspects corresponds to a particular kind of value generated by the e-service, and between them there are usually some relations. Some of these aspects are 'independent' variables, which are under the direct control of the e-service provider, such as the quality of the various capabilities and resources provided to the users. On the contrary, some other quality aspects are 'dependent' variables – outcomes, which are not under the direct control of the e-service provider, but depend on (usually are caused by) the 'independent' ones to some extent, such as the extent of offering assistance to users for performing particular tasks or achieving particular objectives; also, there might be relations between the dependent quality aspects as well, and some of them might depend on both independent and dependent ones. Estimating this network of relations would enable a more complete evaluation of the e-service, a better understanding of its value generation process, and also a rational prioritization of the improvements that should be made in some independent quality aspects (e.g. improvements of some capabilities and resources provided to the users) in order to achieve higher levels of the dependent ones (outcomes).

3. An e-services assessment and improvement methodology

Taking into account the above conclusions of previous literature on e-services evaluation, a structured methodology for assessing and improving e-services has been developed, focusing on the assessment (measurement) of different types of value an e-service generates and the estimation of the relations among them. This methodology is based on the following five layers of evaluation measures:

(a) 'efficiency measures', assessing the quality of the basic resources and capabilities offered by the e-service to its users,
(b) 'context measures', assessing significant aspects of the context in which the e-service is provided,
(c) 'usage measures', assessing the extent of use of the e-service,
(d) 'effectiveness measures', assessing the outcomes of the e-service, e.g. to what extent the e-service assists the users for completing particular tasks, achieving particular objectives, or offers them fun and enjoyment,
(e) 'future behavior measures', assessing to what extent the e-service will influence the future behavior of its users.

Layers (a), (c), (d) and (e) correspond to the main kinds of value generated by an e-service according to the relevant literature reviewed in the previous section, while layer (b) aims to take into account the context, which according to previous literature affects the value generated by IS (Taylor and Todd, 1995; Smithson and Hirscheim, 1998; Jackson, 1998; Melville et al., 2004,

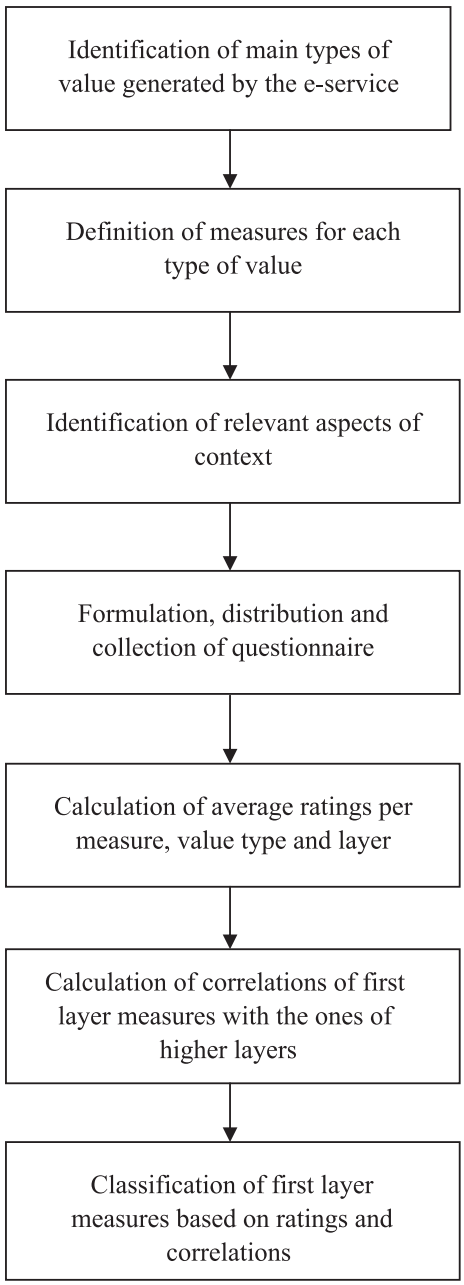

Fig. 1. Stages of the proposed e-services assessment and improvement methodology.

2007); it is widely accepted that the effectiveness of IS depends not only on the resources and capabilities offered to the users, but also on some aspects of the context as well (e.g. individual characteristics and knowledge background of the users). It should be noted that from these measures only the ones of layer (a) (efficiency measures), and to some extent the ones of layer (b) (context measures), are 'independent variables' under the direct control of the e-service provider, who can make interventions for improving the resources and capabilities offered by the e-service, or shape to some extent some aspects of the context (e.g. allowing only people having sufficient skills in using computers and knowledge background to participate in an e-learning course). On the contrary, the measures of the other three layers (c) (usage measures), (d) (effectiveness measures) and (e) (future behavior measures) are 'dependent variables', which are not under the direct control of the service provider, and to some extent depend on (usually being are caused by) the independent ones.

The proposed e-services assessment and improvement methodology consists of the following seven stages (Fig. 1):

(I) Initially are identified the main types of value created by the e-service, which will be the main evaluation dimensions. As mentioned above, they are usually associated with the main resources and capabilities offered by the e-service to its users, the assistance it offers them for completing various tasks or achieving various objectives, the fun and enjoyment it offers them, the influence of the e-service on various aspects of users' future behavior, etc.

(II) For each of these types of value generated by the e-service are defined a number of measures (items) for assessing it. The number of these measures should be sufficient for achieving a complete measurement of the particular type of value, but at the same time should not be too high, since this would result in lengthy questionnaires to be filled by the users and therefore low response rates. A good practice would be to use one or two measures for types of value which are clear and understandable by the users, and several measures for more abstract and complex types of value.

(III) Furthermore, the main relevant aspects of the context of the e-service, which are expected to affect significantly its effectiveness (in addition to the main resources and capabilities offered to the users), are identified.

These first three stages can be characterized as 'design stages', since they aim at designing the measurement model of the value generated by the e-service. It should be based both on previous research (i.e. previous studies proposing evaluation dimensions and items for similar services, and probably context factors affecting significantly its effectiveness) and also on the particular objectives, characteristics, resources, capabilities and context of the evaluated e-service. The following four stages can be characterized as 'application stages', since they aim to apply this measurement model, process collected data and draw conclusions as to the strengths, weaknesses of the e-service and the improvement priorities.

(IV) Based on the evaluation dimensions and measures (items) defined in the stages (I)–(III) a questionnaire is formulated, which is distributed to the users of the e-service, filled by them and collected back.

(V) From the data of the returned filled questionnaires are calculated the average ratings by the users for all measures, and then for all types of value (=evaluation dimensions) and layers; based on these average ratings we can identify the measures, types of value and layers assessed as high by the users, which constitute the 'strengths' of the e-service, and also the ones assessed as low by the users, which are the 'weaknesses' of the e-service.

(VI) Then the correlations of all first layer efficiency measures (quantifying the value associated with the provision of various resources and capabilities to the users) and all second layer context measures are calculated with all the measures of the third layer (quantifying the value associated with the usage of the e-service), the fourth layer (quantifying the value associated with increasing users' effectiveness in completing some tasks or achieving some objectives) and the fifth layer (quantifying the value associated with users' future behavior). Additionally, the correlations of all measures of the third and the fourth layer are calculated with all the measures of the fifth layer. From these correlations conclusions are drawn concerning the relations between the various types of value generated by the e-service and its value generation process.

(VII) Finally the measures of the first layer, which are the only 'independent variables' within the control of the e-service provider, are classified according to their average ratings by the users and their correlations with the measures of the third, fourth and fifth layer (quantifying their impact on the generated 'higher level' value associated with users'

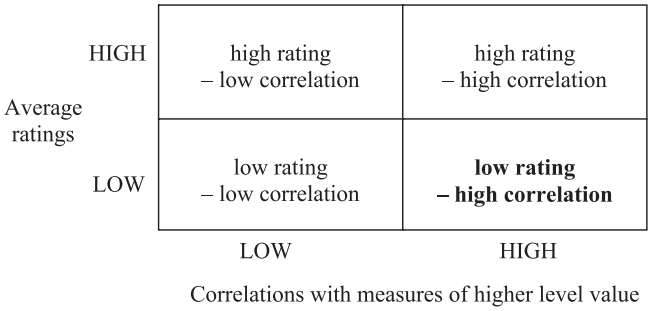

Fig. 2. Classification of the independent first layer measures of resources/capabilities quality.

effectiveness and future behavior) into four groups (Fig. 2): low rating–high correlation, low rating–low correlation, high rating–high correlation and high rating–low correlation. The highest priority should be given to the improvement of the resources/capabilities of the first group (shown in bold in Fig. 2), since they are rated by the users as being of low quality and at the same time have a high impact on the generation of higher levels value. On the contrary, the lowest priority should be given to the improvement of the resources/capabilities of the fourth group, since they are rated as already having high quality and at the same time have a low impact on the generation of higher-level value. Medium priority should be given to the improvement of the resources/capabilities of the second and the third group. Similar can be done with the context variables that the e-service provider can control at least to some extent.

The above structured methodology offers the capability to identify strengths and weaknesses of an e-service concerning not only the final outcomes, but also all the layers of its value generation process. Furthermore, it enables the detection of the origins of those strengths and weaknesses at the previous layers, as well as their impact on the next layers, as well as it allows the definition of priorities concerning improvements of the resources and capabilities in the first layer. It can be very useful in a digital city context, in which various types of innovative e-services are developed, which can be very different from the 'usual' ones, e.g. information portals or e-shops, and providing many different types of value to wide and heterogeneous users groups.

4. Application

The proposed methodology has been applied for the evaluation of an e-learning service, which has been developed for young citizens in the Greek city of Karlovassi, and for the identification and prioritization of necessary improvements of it. Karlovassi is a small city in the Aegean island of Samos, Greece, which hosts three Departments of the University of the Aegean, and has many students and also many young elementary and high school teachers; both these groups are interested in increasing their knowledge and skills by attending short continuous education courses on subjects of their interest. In this city an extensive network infrastructure has been constructed recently, including both fixed and wireless networks. In order to exploit them on one hand and satisfy the above educational needs of the young students and teachers on the other an e-learning service has been developed by the University of the Aegean. It offers several e-courses; in each of them the registered users through the Internet can access educational e-content, communicate with the responsible instructor (e.g. for asking clarification questions on the educational content) and also participate in relevant e-discussions with the other participants and the instructor using a forum tool. At the end of each e-course the registered participants take a 'traditional' written exam.

Initially the value measurement model was designed for this e-learning service, taking into account on one hand previous research on e-learning evaluation (reviewed in 2.3) and on the other the particular objectives, characteristics, resources, capabilities and context of this e-service. We can see it in Fig. 3, which shows the evaluation measures per layer and the hypothesized relations among them. We decided to use one measure for each type of value generated by this

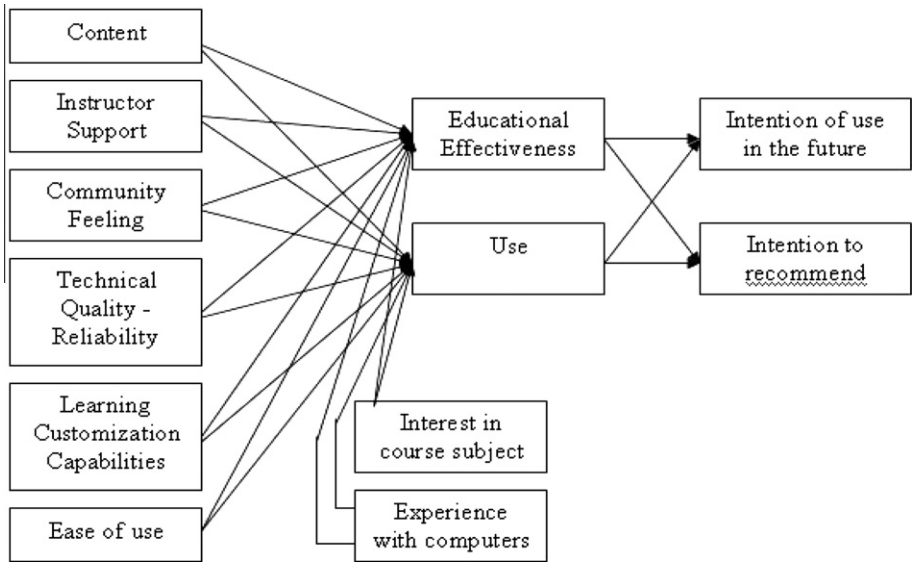

Fig. 3. The multi-layer value measurement model of the e-learning service.

e-learning service because they are all clear and understandable by the users and also in order to keep the corresponding users' questionnaire short and have high response rate. In the Appendix A we can see the supporting literature for each measure.

The first layer includes measures of the main e-learning resources and capabilities offered to the user (in the parentheses are the names of the corresponding variables): content (CONT), electronic support by the instructor (INSUP), development of a community feeling (COMM), technical quality and reliability (TREL), capability to customize the learning process to ones' learning needs and wishes (CUST) and ease of use (EUSE); the assessments of these e-learning resources and capabilities by the users constitute a measure of the first level efficiency-oriented value created by this e-learning service. The second context-oriented layer includes measures of learner's personal characteristics, such as his/her degree of interest in the course subject (INTSUB) and his/her degree of experience with computers (COMPEXP). The third and the fourth layer include measures of higher-level value generated by this e-learning system, associated with its usage (USE) and its educational effectiveness (i.e. how effective the e-learning system was for learning new concepts, facts, methods, technologies, theories, etc.) (EDEFF), respectively. Finally the fifth layer includes measures of learner's intended future behavior with respect to this e-learning service: the degree of his/her intention to use it in the future (FUTUSE) and also to recommend it to colleagues (FUTREC); they constitute measures of future behavior-oriented value created by the service. Based on the above measures a questionnaire was designed to be filled by the users of the service after finishing an e-course, which is shown in Appendix B.

We initially chose a very popular e-course concerning the 'Electronic Management of Cultural Heritage' to be evaluated using the proposed methodology. This e-course had a duration of six weeks and attracted 65 participants; initially they were registered, and then every week they downloaded some educational e-content, studied it, sent clarification questions to the instructor (which were visible by all the other participants together with the answers) and participated in an e-discussion in the forum tool on a topic predefined by the instructor. Immediately after the end of this e-course a 'physical' meeting was organized with all the participants and the instructor. The above evaluation questionnaire was distributed in paper form to all participants at the end of the meeting. The data of the filled questionnaires were processed according to Section 3, and the results are presented in the following Section 5.

5. Results

Based on the ratings given by the participants initially we calculated the average rating for each measure, then for each layer (as the average over all the measures it includes) and finally the global average over all four value layers (as the average over all the measures), which are shown in Table 1. We can see that the average rating over the six efficiency-oriented value measures of the first layer is 4.10, therefore (given that their scale is 1–6 as we can see in Appendix B) the participants perceive a moderately high efficiency value in this e-learning service (i.e. with respect to the e-learning resources and capabilities it offers). By examining the average ratings of the particular measures of this first layer we remark that the highest ones have been given for the electronic support by instructor (INSUP) (4.53), the educational content (CONT) (4.36) and the technical quality and reliability (TREL) (4.36), which constitute strengths of the service, while the lowest average ratings have been given for the ease of use (EUSE) (3.58), the development of a community feeling (COMM) ($1 + 0.58 * (6 - 1) = 3.90$) and the customization capability (CUST) (3.92), which constitute weaknesses of the service (mainly the ease of use). With respect to the second context-oriented layer we can see that the average level of experience

Table 1
Average ratings for all value and context measures.

Measure	Scale	Average rating
Content (CONT)	1–6	4.36
Electronic support by instructor (INSUP)	1–6	4.53
Development of community feeling (COMM)	0–1	0.58
Technical quality and reliability (TREL)	1–6	4.36
Capability to customize the learning process to ones' learning needs and wishes (CUST)	1–6	3.92
Ease of use (EUSE)	1–6	3.58
Efficiency measures average		**4.10**
Usage of the e-learning system (USE)	1–6	4.05
Degree of educational effectiveness (EDEFF)	1–6	4.47
Effectiveness measures average		**4.26**
Intention to use it in the future (FUTUSE)	1–6	3.52
Intention to recommend it to colleagues (FUTREC)	1–6	3.70
Future behavior measures average		**3.61**
Total average		**4.04**
Interest in the course subject (INTSUB)	1–4	2.93
Experience with computers (COMPEXP)	1–4	3.95
Future context measures average		**3.44**

with computers (COMPEXP) is very high (3.95, with four as maximum rating), while the average interest in the subject of the course they attended (INTSUB) is high (2.93/4); therefore we can conclude that the context of this e-course was favorable (average 3.44/4).

In the third layer we can see that the average rating of the usage measure (USE) is medium to high (4.05), therefore this e-service generates a moderately high usage value. Higher is the average rating for the fourth layer measure of the educational effectiveness (EDEFF) of the service (4.47), which constitutes another strength of the service, and indicates that the users perceive a moderately high to high educational effectiveness value of this e-learning service. Finally, in the fifth layer we remark that the average rating over the two future behavior-oriented value measures of it is 3.61, which means that this e-service generates a medium value concerning users' future behavior; the average rating given for the intention to recommend the service to colleagues (FUTREC) (3.70) is slightly higher than the one the for intention to use it in the future (FUTUSE) (3.52), but both constitute weaknesses of the service. The global average rating over all measures of the four value layers is 4.04, therefore the users find that the overall value of this e-learning service is moderately high.

Next we calculated the correlation coefficients between each of the six value measures of the first layer (efficiency measures) and the two value measures of the third layer (usage measure) and the fourth layer (effectiveness measure), as estimates of the impact of the efficiency measures on the usage and effectiveness measures; they are shown in the second and the third column of Table 2. Also in the same columns (in the last two rows) we can see the correlation coefficients between each of the two context measures of the second layer (personal characteristics of the users) and the two value measures of the third and the fourth layer, as estimates of the impact of the context on the usage and effectiveness measures. In this table are shown only the statistically significant correlation coefficients at the 5% level (i.e. with significance lower than 5%), while with 'NS' are denoted correlation coefficients that are not statistically significant, and with an asterisk (∗) are denoted correlation coefficients that are statistically significant at the 10% level but not at the 5% level (i.e. with significance higher than 5% but lower than 10%). We remark that the development of a community feeling (COMM) and the capability to customize the learning process (CUST) are characterized by the highest correlation coefficients with the usage and effectiveness measures, followed by the content (CONT) and the electronic support by instructor (INSUP); all these four efficiency measures have medium level (around 0.5) statistically significant correlation coefficients with the usage and effectiveness measures. On the contrary the ease of use (EUSE) does not have statistically significant correlations with the usage and effectiveness measures, while the technical quality and reliability (TREL) does not have statistically significant correlation with the usage measure, and a small marginally significant (at the 10% significance level) correlation with the effectiveness measure. Also, the degree of experience with computers (COMPEXP) has statistically significant correlation coefficients of lower level with the usage and effectiveness measures, while the interest in the subject of the course (INTSUB) does not have statistically significant coefficients with either. Furthermore, for each of the usage and the effectiveness measures we constructed a regression model, having it as dependent variable and the six efficiency measures and the two context measures as independent variables. The R^2 values were 0.51 for the model of the system usage (USE) and 0.49 for the model of the degree of educational effectiveness (EDEFF). Therefore we can conclude that these eight independent efficiency and context variables can explain about half of the variation of the usage and effectiveness-oriented value measures.

Finally, we calculated the correlation coefficients between each of the usage and effectiveness value measures of the third and fourth layer and the two future behavior-oriented value measures of the fifth layer, as basic estimates of the impact of

Table 2
Correlation coefficients between each of the efficiency/context measures and the measures of usage, effectiveness and future behavior.

	USE	EDEFF	FUTUSE	FUTREC
CONT	0.465	0.412	0.600	0.637
INSUP	0.440	0.473	0.365	0.372
COMM	0.551	0.486	0.270	0.289
TREL	NS	0.197*	NS	NS
CUST	0.482	0.521	0.362	0.483
EUSE	NS	NS	0.469	0.476
INTSUB	NS	NS	0.374	NS
COMPEXP	0.348	0.323	NS	NS

Table 3
Correlations between effectiveness-oriented value measures and future behavior-oriented value measures.

	FUTUSE	FUTREC
USE	0.507	0.534
EDEFF	0.407	0.500

the usage and effectiveness on the future behavior, which are shown in Table 3. We can see that both usage and effectiveness measures have statistically significant correlation coefficients of medium level (around 0.5) with both future behavior measures; we remark that the system usage (USE) has higher levels of correlation coefficients with both future behavior measures than the degree of educational effectiveness (EDEFF). Furthermore, for each of the two future behavior measures (FUTUSE and FUTREC) we constructed a regression model, which had it as dependent variable and the two usage and effectiveness measures as independent variables. The R^2 values of both these models were very low: 0.29 for the model of the intention to use the service in the future (FUTUSE) and 0.35 for the model of the intention to recommend it to colleagues (FUTREC). So we proceeded with adding to each of these two modes the six efficiency measures of the first layer as additional independent variables. The R^2 values of both these two new models (each of them having eight independent variables in total) were much higher: 0.59 for the model of the intention to use the service in the future (FUTUSE) and 0.64 for the model of the intention to recommend it to colleagues (FUTREC); by adding to the independent variables the two personal characteristics (therefore estimating the two models with ten independent variables in total) the R^2 values of both these two new models increased by another 5%. Therefore it is concluded that the usage and effectiveness related value measures can explain about 30% of the variation of the future behavior-oriented value measures; however, together the six effectiveness-oriented value measures and the usage and effectiveness-oriented value measures can explain a much higher percentage of about 60% of the variation of the future behavior-oriented value measures, while by adding the two personal characteristics the percentage of this variation that can be explained rises to about 65%. For this reason we also calculated the correlation coefficients between each of the six efficiency-oriented value measures of the first layer and each of the two future behavior-oriented value measures of the fifth layer; similarly, we calculated the correlation coefficients between each of the personal characteristics and each of the two future behavior-oriented value measures; they are all shown in the fourth and the fifth column of Table 2. We remark that the content (CONT) has the highest correlation coefficients with the two future behavior measures (of medium to high level: 0.600 and 0.637, respectively), followed by the ease of use (EUSE) (0.469 and 0.476, respectively) and the capability to customize the learning process to ones' learning style and needs (CUST) (0.362 and 0.483, respectively).

By combining the results of Table 1 (average ratings for all value measures) with the ones of Table 2 (correlation coefficients between value measures of different levels), we can conclude that our main priorities for the improvement of the resources and capabilities offered by the service should be:

(a) the development and enhancement of a community feeling between the e-learners and the instructor (variable COMM), and
(b) the provision to e-learners of more capabilities to customize the learning process to their learning styles, needs and wishes (variable CUST),

since they are both characterized by low average ratings by the participants and high impact on the creation of higher levels value associated with usage, effectiveness and users' future behavior.

6. Conclusions and further research directions

Many cities all over the world implement various 'digital city' projects constructing big network infrastructures, which aim to offer to local public organizations, businesses and houses high speed connectivity, and on top of them various kinds of e-services aiming at both economic and social objectives. These e-services are of vital importance for the exploitation of the network infrastructures and the generation of value from them for local businesses and citizens. The appropriate assessment and gradual improvement of the developed e-services is therefore of critical importance for the advancement of 'digital cities'. In the previous sections has been presented a structured methodology for assessing and improving such e-services, which focuses on the assessment of the different types of value an e-service generates and the estimation of the relations among them. This methodology is based on five layers of evaluation measures: 'efficiency measures' (assessing the quality of the basic resources and capabilities offered by the e-service to its users), 'context measures' (assessing significant aspects of the context in which the e-service is provided), 'usage measures' (assessing the extent of use of the e-service), 'effectiveness measures' (assessing e-service outcomes, such as to what extent the e-service assists the users for completing particular tasks, achieving particular objectives, or offers them fun and enjoyment) and 'future behavior measures' (assessing to what extent the e-service will influence the future behavior of its users). It consists of seven stages: the first three of them aim at designing the appropriate measurement model of the value generated by the particular e-service (i.e. at the definition of evaluation dimensions and measures/items), based on one hand on previous relevant literature and on the other on the particular objectives, characteristics, resources, capabilities and context of the evaluated e-service; the next four stages aim to apply this measurement model, process the collected data and draw conclusions as to the strengths, weaknesses of the e-service and the improvement priorities.

A first application and validation of the proposed methodology has been made, aiming at the evaluation of an e-learning service developed for young citizens in the Greek city of Karlovassi, and the identification and prioritization of the necessary improvements of it. It was concluded that according to the users the overall value of this e-learning service is moderately high; in particular it creates a moderately high e-learning resources and capabilities value, a mod-

erately high usage value, a moderately high to high educational effectiveness value and finally a medium value concerning influence on users' future behavior. Its main strengths are the educational e-content, the electronic support by the instructor, the technical quality and reliability and the educational effectiveness; on the contrary it has weaknesses concerning its ease of use, the customization capabilities, the development of community feeling between the e-learners and the instructor and the influence on users' future behavior. Also, from the first layer resources and capabilities it was found that the customization capabilities and the development of a community feeling have the highest impact on the usage and educational effectiveness, followed by the educational e-content and the electronic support by instructor; concerning the context, it was found that the experience with computers has a lower impact on both usage and educational effectiveness, while the interest in the subject of the course does not have a statistically significant impact on either of them. Both usage and educational effectiveness have similar impact on both future behavior measures. Finally it has been concluded that our improvement priorities should be the development and enhancement of a community feeling between the e-learners and the instructor, and the provision to e-learners of more capabilities to customize the learning process to their learning styles, needs and wishes, since they are both characterized by low average ratings by the users and high impact on the creation of higher levels value associated with usage, effectiveness and users' future behavior.

The research described in this paper makes a significant contribution to the research and practice in the area of e-services, by proposing and validating a methodology that enables a more complete and structured evaluation of an e-service, a detailed assessment the various types of value it generates and the relations among them, a deeper understanding of its value generation process and also a prioritization of the improvements that should be made in the resources and capabilities offered by the e-service. This methodology can result in significant improvements in the practices of e-services' design and delivery in the 'digital cities' all over the world, and therefore in higher exploitation of the network infrastructures constructed, and finally in the generation of more value from them for local businesses and citizens. Also, the proposed approach of multi-level evaluation of e-services (discrimination of different types and levels of value and estimation of relations among them) can be useful for the future research in this area, since it can enable a better analysis and in-depth understanding of the numerous types of e-services, which are operational or under development by both private and public sector organizations.

A limitation of this study is that the proposed methodology has been applied and validated only in one e-service, which has been used and evaluated by a group of young people with rather high educational level and computer skills; however, in the 'real life' there are many different types of e-services (operational or under development) in the 'digital cities', which are used (or planned to be used) by various citizens groups of different ages, education and computer skills. Another limitation is that the value measurement we designed for this first application/validation of our methodology included only one measure for each type of value generated by this e-learning service, in order to keep the users' evaluation questionnaire short; this might reduce the reliability in the estimations of the various types of value generated and the relations among them. Therefore further research is required towards the application and validation of the proposed methodology in other types of e-services in various contexts and user groups, using more evaluation measures per evaluation dimension (type of value generated) and based on larger users' groups. Also, it would be interesting to investigate the use of not only correlations and regression modeling for investigating the relations among the various types of value generated, but also more advanced modeling techniques as well, such as structural equation modeling.

Appendix A. Supporting literature for the e-learning service evaluation measures

Educational content	Ehlers (2004, 2005), Shee and Wang (2008) and Ozkan and Koseler (2009)
Instructor support	Volery and Lord (2000), Soong et al. (2001), Selim (2005) and Ozkan and Koseler (2009)
Learning community	Volery and Lord (2000), Soong et al. (2001), Selim (2005) and Shee and Wang (2008)
Technical quality	ISO/IEC 9126 (2001), Ehlers (2005), Parasuraman et al. (2001) and Ozkan and Koseler (2009)
Customization capabilities	Wang (2003), Shee and Wang (2008), Ozkan and Koseler (2009) and Paechter et al. (2010)
Perceived ease of use	Soong et al. (2001), Parasuraman et al. (2005), Selim (2003) and Shee and Wang (2008)
Educational effectiveness	Lorenzo and Moore (2002), Selim (2003), Liu and Khalifa (2003) and Paechter et al. (2010)
Use	DeLone and McLean (2003), Davis (1989) and Selim (2003)
Intention to use	Saade and Bahli (2005), Selim (2003), Ngai et al. (2005) and Chiu et al. (2005)
Context	Taylor and Todd (1995), Jackson (1998), Melville et al. (2004) and Lim et al. (2007)

Appendix B. Questions, scales and range of answers of the survey instrument

Questions	Scale	Range
The educational content of the e-course you participated in was very good	1–6	"Strongly disagree"–"Strongly agree
The overall electronic support by the instructor was very good	1–6	"Strongly disagree"–"Strongly agree
In your opinion, was the development of a community feeling possible?	0–1	"Yes"–"No"
To which degree are you satisfied with the technical reliability of this e-learning service in general?	1–6	"Very unsatisfied"–"Very satisfied"
This e-learning service offers the opportunity to customize the learning process according to your learning needs and wishes	1–6	"Strongly disagree"–"Strongly agree
To which degree the sequence of operations to perform the necessary tasks were easy to remember and repeat?	1–6	"Strongly disagree"–"Strongly agree
I have profoundly used this e-learning service while participating in the e-course	1–6	"Strongly disagree"–"Strongly agree
This e-learning service offered me the opportunity to improve knowledge (learn new concepts, terms, methods, technologies, etc.) on the topic of the e-course I took part in	1–6	"Strongly disagree"–"Strongly agree
I would attend another e-course on a similar subject provided by the same e-learning service	1–6	"Strongly disagree"–"Strongly agree
I would recommend this e-learning service to other students	1–6	"Strongly disagree"–"Strongly agree
Assess your level of your previous experience in using computers	1–4	"None"–"Very high"
Assess your level of your previous interest in the course subject	1–4	"None"–"Very high"

Note: at the end of each question there were additional information, definitions and explanations provided, wherever needed (e.g. "electronic support" = electronic answers to questions, the use of the forum tool among students and the instructor to share common interests, etc.).

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