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Evaluation of Quality of Personalised Learning Scenarios: An Improved MCEQLS AHP Method*

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The aim of the paper is to investigate and present a comprehensive scientific model and a novel method of consecutive four steps application of Analytic Hierarchy Process (AHP) for the expert evaluation of the quality of learning scenarios. The paper pays a special attention to learning scenarios suitability to particular learner groups (i.e. learning styles). Solution of learning scenarios quality evaluation and optimisation problems could help educational institutions to select suitable learning scenarios for the particular learner groups. Several well-known scientific principles are applied to create a comprehensive quality model (criteria system) for evaluating learning scenarios. The research results will be implemented in iTEC—a four-year, pan-European research and development project focused on the design of the future classroom funded by EU 7FP. Several practical examples of iTEC learning scenarios have been evaluated against the proposed model and method. The research results have shown that a novel method of four steps application of AHP both for establishing weights and ratings (values) of the quality criteria is suitable to solve learning scenarios multiple criteria evaluation and optimisation tasks for particular learning styles.

Keywords: learning scenarios; Analytic Hierarchy Process; expert evaluation; multiple criteria decision analysis; optimisation methods; quality criteria; learning styles

1. Introduction

The aim of the paper is to investigate, propose, and demonstrate examples of practical application of a model and method suitable for the expert evaluation of the quality of learning scenarios (LS). A special attention is paid to LS suitability to particular learner groups (i.e. learning styles).

The practical problem analysed in the paper is how to choose the best LS alternative in the market or create it. Here 'the best' alternative means an alternative of the highest quality. Scientific problem of creation of the proper model and methods for the expert evaluation of the quality of LS is necessary for the educational institutions. They need to have a suitable instrument to choose the best LS alternatives in the market or create qualitative LS. The main problem here is how to elaborate quite objective, exact, and simple to use approaches, models, and methods for choosing the qualitative alternatives of LS software.

The term of 'learning scenario' (also known as 'Unit of Learning') is referred here as an aggregation of learning activities (LA) that take place in particular virtual learning environments (VLE) using particular learning objects (LO).

This notion is based on [1] and [2]. Quoting [2], 'a 'Unit of Learning' refers to a complete, self-contained unit of education or training, such as a course, a module, a lesson, etc.' [1] conceptual vocabulary clarifies that a 'unit of learning' is an abstract term used to refer to any delimited piece of education or training. It is noted that a 'unit of learning' represents more than just a collection of ordered resources to learn, it includes a variety of prescribed activities (problem solving activities, search activities, discussion activities, peer assessment activities, etc.), assessments, services and support facilities provided by teachers, trainers and other staff members. A learning design as an integral part of any unit of learning is a description of a method enabling learners to attain certain learning objectives by performing certain learning activities (LA) in a certain order in the context of a certain learning environment.

According to [1], learning activities are one of the core structural elements of the 'learning workflow' model for learning design. They form the link between the roles and the LOs and services in the learning environment. The activities describe a role they have to undertake within a specified environment composed of LOs and services. Activities take place in a so-called 'environment', which is a structured collection of LOs, services, and sub-environments.

LO is referred here as any digital resource that can be reused to support learning [3]. VLE is referred here as a single piece of software, accessed via

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standard Web browser, which provides an integrated online learning environment [4]. Therefore, we can conclude that LS could consist of learning activities, learning objects and learning environment referred here as services package. This kind of services package in e-learning theory is commonly known as VLE (also known as Learning Management System). Thus we can divide LS into three components, namely LA, LOs and VLE.

Evaluation is a process by which people make judgements about value and worth [5]. Quality evaluation is a systematic examination of the extent to which an entity (part, product, service or organisation) is capable of meeting specified requirements [6]. Expert evaluation is a multiple criteria evaluation of learning software aimed at the selection of the best alternative based on score-ranking results [4].

According to [7], despite the recent advances of the electronic technologies in e-learning, a consolidated evaluation methodology for the e-learning applications is not available. The evaluation of the educational software must consider its usability and more in general its accessibility, as well as its didactic effectiveness. According to [8], despite the widespread use of the e-learning systems and the considerable investment in purchasing or developing them, there is no consensus on a standard framework for evaluating the system quality.

Probably the most popular classification of the learning styles among educational researchers is one developed by [9], based upon the work of [10]. They identified four distinct learning styles or preferences, namely, Activist, Theorist; Pragmatist and Reflector as follows:

(1) Activist: activists are those people who learn by doing. Have an open-minded approach to learning, involving themselves fully and without bias in new experiences. Their preferred activities are: brainstorming, problem solving, group discussion, puzzles, competitions, and role-play.
(2) Reflector: these people learn by observing and thinking about what happened. They prefer to stand back and view experiences from a number of different perspectives, collecting data and taking the time to work towards an appropriate conclusion. Their preferred activities are: paired discussions, self analysis questionnaires, personality questionnaires, time out, observing activities, feedback from others, coaching, and interviews.
(3) Pragmatist: these people need to be able to see how to put the learning into practice in the real world. Abstract concepts and games are of limited use unless they can see a way to put the ideas into action in their lives. They are experimenters, trying out new ideas, theories and techniques to see if they work. Their preferred activities are: time to think about how to apply learning in reality, case studies, problem solving, and discussion.
(4) Theorist: these learners like to understand the theory behind the actions. They need models, concepts and facts in order to engage in the learning process. Prefer to analyse and synthesise, drawing new information into a systematic and logical 'theory'. Their preferred activities are: models, statistics, stories, quotes, background information, and applying theories.

In the paper, the authors aim to present the quality and suitability of LS to the only learner profile, namely, activist learners. The main reason for this is that iTEC [11] scenarios selected to demonstrate practical application of the novel evaluation method are mostly suitable for the activist learning style.

The rest of the paper is organised as follows: methodology of the research is presented in Section 2, literature analysis and research results are presented in Section 3, and conclusion and recommendations—in Section 4.

Section 3 containing research results is divided into two separate parts:

(1) creating LS quality model (criteria system) and the method of consecutive four steps (stages) application of AHP for evaluating LS quality, and
(2) demonstrating a practical example of evaluating several real-life LS alternatives analysed in EU 7FP iTEC project [11].

2. Research methods

According to [12], there is a wide range of multiple criteria decision making problem solution techniques, varying in complexity and possible solutions. Each method has its own strength, weaknesses and possibilities to be applied. Usually the experts have to deal with the problem of optimal decision in the multiple criteria situation where the objectives are often conflicting. In this case, an optimal decision is the one that maximises the expert's utility.

Evaluation of quality of LS alternatives is a typical case where quality criteria are conflicting, i.e. LS could be very qualitative against several criteria, and not qualitative against the other ones, and vice versa.

Therefore, the authors propose to use multiple criteria decision analysis (MCDA) based approach for creating LS quality model. In order to construct a proper comprehensive scientific quality criteria system (model), the authors use the well known principles of identification of the quality criteria proposed in [13]. Practical application of these principles will be described below while analysing LS quality criteria model.

In the model, the authors also apply technological quality criteria division principle claiming that one should evaluate learning software alternatives using two different groups of evaluation criteria—'internal quality' and 'quality in use' criteria. According to [14], based on international software quality standard [15], 'internal quality' is a descriptive characteristic that describes the quality of learning software independently from any particular context of its use, and 'quality in use' is evaluative characteristic obtained by making a judgment based on criteria that determine the worthiness of software for a particular project or user / group (e.g. activist learners in our case).

LS multiple criteria evaluation method used by the authors is referred here as the experts' additive utility function represented by formula (1) including LS evaluation criteria, their ratings (values) and weights.

$$f(X) = \sum_{i=1}^{m} a_i f_i(X) \tag{1}$$

where $f_i(X)$ is the rating (value) of the criterion i for the each of the examined LS alternatives X. The weights here should be 'normalised' according to the 'normalisation' requirement (2):

$$\sum_{i=1}^{m} a_i = 1, a_i > 0. \tag{2}$$

The major is the meaning of the utility function (1) the better is the alternative.

The approach based on the aforementioned principles of creating a model and use of the formula (1) to obtain final evaluation results is called MCEQLS—Multiple Criteria Evaluation of Quality of Learning Software [4].

The complexity of the analysed problem influences the application of more complex methods for evaluating the quality of LS from the point of view of different learner groups.

In this paper, a novel method of consecutive four steps application of AHP (see section 3.2.1) is used to establish proper weights and ratings (values) of LS quality criteria in the case when there are several experts evaluators. According to the method, the proper comparative weights of LS are established while implementing 1st–3rd steps, and comparative ratings (values) of LS are established in the 4th step. In the present research, three iTEC [11] experts (incl. the authors of the paper) took part in evaluation of iTEC scenarios.

After application of a novel method of consecutive four steps application of AHP, formula (1) is used to calculate the values of the experts' additive utility functions (1) for each of the explored LS alternatives.

This MCEQLS approach [4] enriched by the method of consecutive four steps application of AHP is referred here as an improved MCEQLS AHP method.

3. Presentation and discussion

3.1 Learning scenarios quality model

According to [16], decision criteria are rules, measures and standards that guide decision-making. [17] proposed a general definition of a quality criterion as a tool allowing comparison of alternatives according to a particular point of view. When building a criterion, the analyst should keep in mind that it is necessary that all the actors of the decision process adhere to the comparisons that will be deduced from that model.

Criteria (relatively precise, but usually conflicting) are measures, rules and standards that guide decision-making, which also incorporates a model of preferences between the elements of a set of real or fictitious actions [12].

According to [13], in identifying criteria for the decision analysis, the following considerations (i.e. principles) are relevant to all the multiple criteria decision analysis approaches:

(1) Value relevance: are the decision-makers able to link the concept to their goals that enable them to specify the preferences which relate directly to the concept?
(2) Understandability: it is important that decision-makers would have a shared understanding of the concepts to be used in the analysis.
(3) Measurability: the MCDA imply some degree of measurement of the performance of the alternatives against the specified criteria, thus it should be possible to specify that in a consistent manner. According to [13], it is usual to decompose criteria to the level of detail which allows that.
(4) Non-redundancy: the decision-makers should define whether there is more than one criterion measuring the same factor. When eliciting ideas, the same concept may often arise under different headings. One can easily check the criteria which appear to be measuring the same thing by e.g. calculating a correlation coefficient, if appropriate data are available.
(5) Judgmental independence: decision-makers

should keep in mind that the evaluation criteria are not judgementally independent, if the preferences with respect to a single criterion, or trade-offs between two criteria, depend on the level of another.

(6) Balancing completeness and conciseness: a number of authors note that desirable characteristics of the value tree are that it is complete, i.e., that all the important aspects of the problem are captured, and also that it is concise, keeping the level of detail to the minimum required.

(7) Operationality: the model should be usable with a reasonable effort, i.e., the information required does not place excessive demands on the decision-makers. The context in which the model is being used is clearly important in judging the usability of the model.

(8) Simplicity versus complexity: the value tree, or a set of criteria, is itself a simple representation, capturing the essence of a problem that has been extracted from the complex problem description. The modeller should strive for the simplest tree which adequately captures the problem for the decision-maker.

LS quality model based on these MCDA criteria identification principles is presented in Fig. 1. The model consists of three groups of quality criteria (i.e. components of LS), namely LOs, LAs and VLEs.

The selection of criteria is based on literature analysis [18], MCDA criteria identification principles [13], and technological criteria division principle [14, 15].

Furthermore, sets portrait method was used to analyse correspondence between the software quality characteristics [15] and LS quality criteria, on the one hand, and between activist learner characteristics and LS 'quality in use' criteria, on the other.

The model consists of already created LOs and VLEs quality criteria systems accordingly presented in [4, 18, 19] and also of LA quality criteria system created for the present research.

LA quality criteria were proposed by iTEC working groups, and a number of scientific papers [20–22] were additionally analysed to propose LA quality criteria.

Principles [13] were applied to form the present system of criteria. The authors have paid special attention to Non-redundancy, Judgemental independence, Balancing completeness and conciseness, and Simplicity Vs complexity principles to create the comprehensive criteria tree presented in Fig. 1.

There is also a clear division of all the criteria into 'internal quality' and 'quality in use' criteria presented in this model.

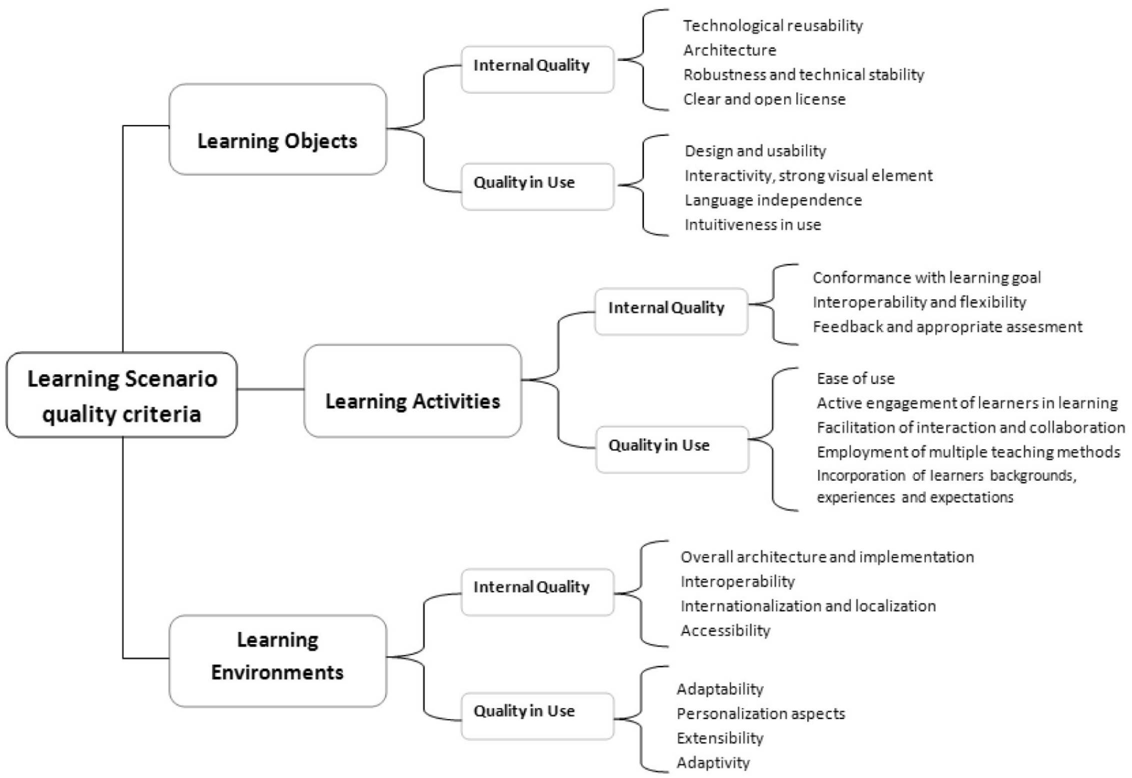

Fig. 1. Learning scenario quality model (criteria tree).

3.2 Learning scenarios quality evaluation methods

3.2.1 Method of consecutive four steps application of analytic hierarchy process to establish the weights and values of the quality criteria

In the paper, the authors propose an original method of consecutive four steps application of AHP to establish proper weights (1st–3rd steps) and ratings (values) (4th step) of LS quality criteria in the case when there are several expert evaluators.

According to [23, 24], AHP is a useful method for solving complex decision-making problems involving subjective judgment. In AHP, the multi-attribute weight measurement is calculated via pair-wise comparison of the relative importance of two factors. The design of the questionnaire incorporates pair-wise comparisons of decision elements within the hierarchical framework. Each evaluator is asked to express relative importance of two criteria in the same level by a nine-point rating scale. After that, one has to collect the scores of pair-wise comparison, and form pair-wise comparison matrices for each of the evaluators.

According to [23], the fundamental scale of absolute numbers is as presented in Table 1.

The proposed novel method consists of application of AHP in four consistent steps. This method is based on LS quality model presented in Fig. 1 and technological quality criteria division principle presented in Section 2.

The proper comparative weights of LS are established while implementing 1st–3rd steps, and comparative ratings (values) of LS are established in the 4th step. Four consistent steps (stages) of AHP application to evaluate LS alternatives are as follows:

(1) AHP-1: establishment of comparative weights of three different groups of LS quality criteria (LOs, LA and VLE) and weights a_i of all the quality criteria.
(2) AHP-2: establishment of comparative weights of 'internal quality' and 'quality in use' criteria groups from the activist learner point of view. The final 'internal quality' criteria weights are established in this stage.
(3) AHP-3: establishment of final weights of criteria from the activist learner point of view by additional application of AHP only for 'quality in use' criteria (see Fig. 2).
(4) AHP based comparison of alternatives against quality criteria ratings (values).

3.2.2 Practical example of evaluation of iTEC project learning scenarios

Two LS alternatives proposed by iTEC project [11] experts were chosen to demonstrate application of the aforementioned method for evaluating LS quality:

Table 1. Pair-wise comparison scale for AHP preferences

Numerical rating	Verbal judgements of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

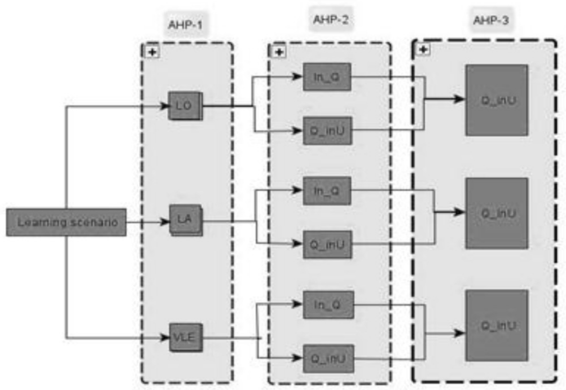

Fig. 2. Method of consecutive triple application of AHP for establishing criteria weights.

LS_1: 'A Breath of Fresh Air' (cycle 1 detailed scenario available at iTEC [11] scenarios library)

LS_2: 'Online Repositories Rock' (cycle 1 detailed scenario online at iTEC [11] scenarios library)

iTEC scenarios are presented not in IMS LD package form, but in narrative form that is more convenient for teachers to validate the scenarios. These scenarios do not contain any particular LOs and VLEs. Use of particular LOs and VLEs is up to decision of every country participating in iTEC. Therefore, in the paper, it was decided to consider LOs and VLEs of the equal quality for both LS alternatives.

Application of the aforementioned method of four stages application of AHP has shown the following results:

Stage 1: weights of criteria groups: LOs – 39.7%, LA – 39.7%, and VLE – 20.6%. Weights a_i for all 24 LS quality criteria were also calculated in conformity with AHP (see Fig. 3).

Stage 2: weights of 'quality in use' criteria in comparison with 'internal quality' criteria are as follows: 69.4% Vs 30.6% for LOs, 72.2% Vs 27.8% for LA, and 61.1% Vs 39.8% for VLE (see Fig. 3).

Stage 3: weights of 'quality in use' criteria are re-established for the activist learners (see Fig. 3).

Stage 4: LS alternatives are compared against

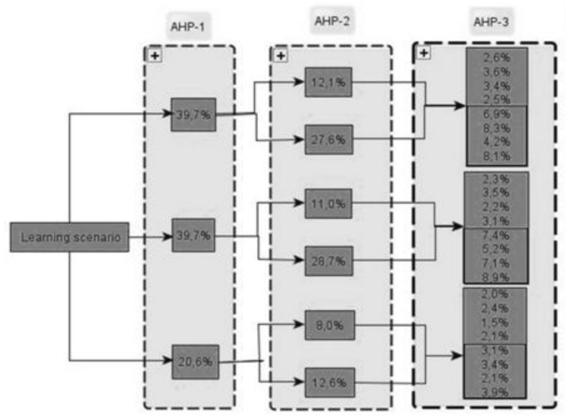

Fig. 3. Weights of iTEC learning scenarios quality criteria.

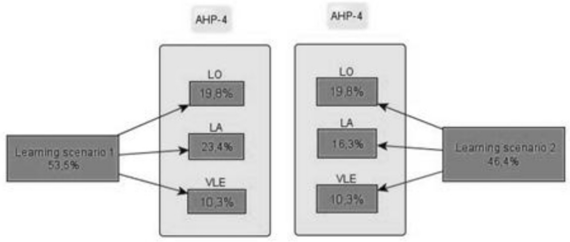

Fig. 4. Final evaluation results after 4th AHP application stage.

quality criteria ratings. In this stage, the experts consider the equal values for LO and VLE components of LS.

Final evaluation results obtained by application of the experts' additive utility function (1) are as follows (Fig. 4):

$$a_{iA} \cdot f(X_j) = (\,0,535 \quad 0,464\,)$$

These results mean that LS_1 is 7.1% better than LS_2 for the activist learners.

Similar tendency is noticeable in the first stage of the large scale validation of those scenarios in iTEC project. Analysis of participation of Lithuanian teachers and classes in September–October 2011 has shown that LS_1 seems more promising alternative for teachers in comparison with LS_2 – 67 classes prefer to validate LS_1, and only 41 – LS_2.

4. Conclusions

Research results presented in the paper show that improved MCEQLS AHP method consisting of:

(1) complex application of MCDA principles and quality criteria division principle,
(2) experts' additive utility function (see formula (1)), and
(3) the original method of four steps application of AHP to establish criteria weights and values (a) is applicable in real life situations when educational institutions have to decide on use of particular LS for their education needs, and (b) could significantly improve the quality of expert evaluation of LS by noticeably reduce of the expert evaluation subjectivity level.

Experimental evaluation results show that proposed scientific approaches are quite objective, exact and easy to use for selecting qualitative LS alternatives for particular learner groups.

On the other hand, the proposed LS personalised quality evaluation approaches are applicable for the aims of iTEC project in order to select LS suitable for the activist learners. Therefore, these approaches have been recommended by the authors to be widely used by European policy makers, publishers, practitioners (teachers), and experts-evaluators both inside and outside iTEC project to evaluate the quality and personalisation level of learning scenarios.

Method of consecutive four steps application of AHP presented in the paper is absolutely novel, and this new element makes the given work distinct from all the other earlier works in the area.

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References

1. IMS LD (Learning Design) Information Model. Version 1.0 Final Specification, 2003, http://www.imsglobal.org/learningdesign/, Accessed 9 July 2012.
2. E. J. R. Koper and C. Tattersall, *Learning Design: A handbook on Modelling and delivering Networked Education and Training*, Heidelberg: Springer, 2005.
3. D. A. Wiley, *Connecting Learning Objects to Instructional design Theory: a definition, a Metaphor, and a Taxonomy*, Utah State University, 2000, http://www.reusability.org/read/, Accessed 9 July 2012.
4. E. Kurilovas, and V. Dagiene, *Evaluation of Quality of the Learning Software. Basics, Concepts, Methods*, Monograph.—LAP LAMBERT Academic Publishing, Saarbrücken, Germany, 2010.
5. M. Oliver, An introduction to the Evaluation of Learning Technology. *Educational Technology & Society*, **3**(4), 2000, pp. 20–30.
6. International Standard ISO/IEC 14598-1:1999: Information Technology—Software Product Evaluation—Part 1: General Overview, 1st ed., 1999-04-15
7. C. Ardito, M. F. Costabile, M. De Marsico, R. Lanzilotti, S. Levialdi, T. Roselli and V. Rossano, An approach to usability evaluation of e-learning applications, *Univ. Access Inf. Soc.*, **4**, 2006, pp. 270–283.
8. B. B. Chua and L. E. Dyson, Applying the ISO9126 model to the evaluation of an elearning system. In: R. Atkinson, C. McBeath, D. Jonas-Dwyer & R. Phillips (Eds), *Beyond the comfort zone: Proceedings of the 21st ASCILITE Conference*, Perth, 5–8 December, 2004, pp. 184–190.
9. P. Honey and A. Mumford, *Manual of Learning Styles*, London: P Honey, 1992.

10. D. A. Kolb, *Experiential Learning: experience as the source of learning and development,* Englewood Cliffs, Prentice Hall, 1984.
11. iTEC (Innovative Technologies for an Engaging Classroom): EU 7FP project website, 2011, http://itec.eun.org/web/guest/, Accessed 9 July 2012.
12. E. K. Zavadskas and Z. Turskis, A new additive ratio assessment (ARAS) method in multicriteria decision-making, *Technological and Economic Development of Economy* **16**(2), 2010, pp. 159–172.
13. V. Belton and T. J. Stewart, *Multiple criteria decision analysis: an integrated approach*, Kluwer Academic Publishers, 2002.
14. J. Gasperovic and A. Caplinskas, Methodology to evaluate the functionality of specification languages, *Informatica* **17**(3), 2006, 325–346.
15. International Standard ISO/IEC 9126-1:2001(E): Software engineering—Product quality—Part 1: Quality model, 2001.
16. M. Zeleny, *Multiple Criteria Decision Making*, New York: McGraw-Hill, 1982.
17. D. Bouysou, Building criteria: A perquisite for MCDA. In: Bana a Costa, C. A. (Ed.). *Readings in Multiple Criteria Decision Aid.* Berlin: Springer-Verlag, 1990, pp. 319–334.
18. E. Kurilovas and V. Dagiene, Learning Objects and Virtual Learning Environments Technical Evaluation Criteria, *Electronic Journal of e-Learning*, **7**(2), 2009, pp. 127–136.
19. J. P. Leal and R. Queirós, Integrating the LMS in Service Oriented eLearning Systems, *International Journal of Knowledge Society Research*, **2**(2), 2011, pp. 1–12.
20. iCOPER (Interoperable Content for Performance in a Competency-Driven Society) EU eContentplus Programme's Best Practice Network web site. D. 3.1. Annex A., 2011, http://www.icoper.org/, Accessed 9 July 2012.
21. D. Y. Shee and Y.-S. Wang, Multicriteria evaluation of the web-based e-learning system: a methodology based on learner satisfaction and its application. *Computers and Education*, **50**(48), 2008, pp. 894–905.
22. P.-C. Sun, R. J. Tsai, G. Finger, Y.-Y. Chen and D. Yeh, What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers and Education*, **50**, 2008, pp. 1183–1202.
23. T. L. Saaty, Relative Measurement and its Generalization in Decision Making: Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors—The Analytic Hierarchy/Network Process, *Review of the Royal Spanish Academy of Sciences*, *Series A*, *Mathematics*, **102**(2), 2008, pp. 251–318.
24. T. L. Saaty, How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, **48**(1), 1990, pp. 9–26.

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