E-Learning Usability: An Mathematical Approach to the Estimation of Learners

Valentina Terzieva, Yuri Pavlov, Rumen Andreev

Abstract: *E-learning usability is a goal of the user - centred e-learning design. Its achievement depends on the determination of the requirements and preferences of the users of an e-learning system or environment (learner, teacher and administrator of an educational process). This paper presents an approach to estimation of learner's preferences that have to influence the teaching process in the creation of suitable learning resources. The determination of the learning style of a learner is an element of the adaptation technique that is necessary for the representation of an adaptive e-learning environment.*

Key words: *E-learning Usability, Adaptive E-learning Environment, Utility Function, Estimation, User Centred Design*

INTRODUCTION

During the last decade the usability engineering gained great popularity along with the growth of the computer-based educational applications. But many educational professionals fail to stress the importance of usability or put it into practice. Therefore we think that it is worth spending time and efforts to consider e-learning usability.

E-learning is an implementation of a teaching-learning process in a computer-based environment. E-learning design as each one design process has two aspects that originate a constructive design approach and an approach to harmonization with the user(s). E-learning design is a constructive task that organizes the components of a computer-based environment in an e-learning system for the purposes of a teacher/ school administrator. The e-learning system is the framework of the e-learning environment that supplies learners with resources, which are necessary for their activities (Fig. 1). The harmonization of e-learning with its users is an objective of the user centered design. The latter is closely linked with the concept of usability, which comes from the field of Human Factors (also known as Ergonomics). Human Factors is a form of engineering, which puts the human at the centre of design rather than machines and equipments. Hence, the constructive aspect of e-learning design presents a system-oriented approach to design. The user centered design takes as its basic premise the view that product development should be driven from user requirements and preferences rather than from technological capabilities.

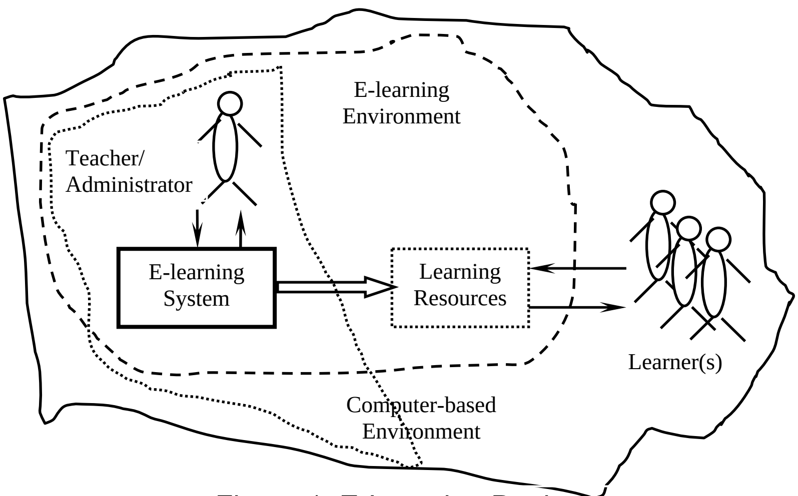

Figure 1. E-Learning Design

The e-learning system supports a teacher/ school administrator to achieve his educational objectives and ensure learning resources. When it helps an administrator of an educational organization in his work, this system is known as Learning Management System. If it helps the management of instructional resources and implementation of different instructional strategies, it is an e-learning instructional system [1]. The learning resources perform a dual role: they are products of instructional activities and elements of which a learner-instructor interface consists. This interface meets the needs of the learner(s) during the educational process. The learning resources have to ensure all possible types of interaction between a learner and an instructor in an e-learning environment. These interactions present e-learning activities that include all learner and instructional activities. The learning resources are a consequence of the instructional activities that implement different instructional strategies for [2]: the identification, evaluation and integration of a variety of information; collaboration, discussion and communication of ideas; participating in simulated experience, apprenticeships and cognitive partnership; the examination of learners. At the same time, the learning resources supply the following learner activities:

- Accessing information – learners identify instructional materials (learning objects) relevant to their educational objectives and access them;
- Scanning information – learners search for particular headings, information items or instructions related to their problem representation;
- Understanding information;
- Transferring information during a discussion or exercises.

Usability is about producing products and systems that are easy to use and perform the function for which they were design. Usability engineering and user center design help designers to ensure that their product and system will meet the needs of the users for whom it is intended. This approach requires the identification of the users that need a service or product and desired product characteristics. Also usability characterizes the interaction between a person and a product or device. For the determination of usability of a product or system, the concept of usability is broken down into the following measurable elements: effectiveness (the possibility for performance of certain task), efficiency (in terms of resources, time and task support), usefulness (to do what we want to do), users' satisfaction.

E-learning usability has two aspects: the usability of e-learning systems and the usability of e-learning resources. The focus of e-learning usability determination is on the e-learning system usability and more specially the assessment of the effectiveness and efficiency of the computer technologies that are used for supporting of teacher/administrator tasks [3]. This assessment bases on usability tests, field studies and heuristic evaluation [4].

This paper presents an approach to the production of usable e-learning resources that have to ensure efficient learner's activities, i.e. a usable learner-instructor interface. Since a usable interface is guaranteed by adaptive interactions, we suggest achievement of e-learning usability by a learner-adaptive production of learning resources. It concerns the development of an adaptive e-learning environment that depends on the used adaptation technique [5]. The latter is determined by the answers of the following questions: *what* would be adapted, *how* it is to be adapted and *what* is the condition it is to be adapted to. We decide to adapt learning resources, which are a component of the learning environment, to the learner's characteristics.

The second section of the paper describes elements of our adaptation technique that adapts the learning resources to learner's preferences. The third section presents an approach to the estimation of learner preferences. The fourth section gives an example of the teacher estimation of learner's preferences about the form of learner examination.

ELEMENTS OF THE USED ADAPTATION TECHNIQUE

The usability of e-learning resources can be viewed from both sides - teacher's and learner's which share one and the same educational goal. From teacher's point of view usability is grounded on designing reusable learning materials, which could be reused in different context, based on constructive learning theory and applying variety of pedagogical approaches and instructional scenarios in order to achieve declared educational goal. From student's point of view, usability means to be available such learning resources and tools allowing them to find this ones that suit them most and then using them in learning process to help them achieving their educational goals. Therefore usable learner-teacher interface has to be:

- Useful – to help achieving predefined educational goal through providing appropriate learning materials and conditions;
- Effective – to allow easily performing of all learning activities in a quick and proficient manner;
- Adaptable – to allow variety paths in the process of knowledge acquisition and checking, i.e. some kind of personalisation;
- Encouraging – allowing users to perform their best.

Usually usability of some product is evaluated a posterior. They test already created product if it satisfies some heuristics or tests [4]. We assert that this approach isn't appropriate in case of the learning process implementation. If one discovers at the end of some learning course that it is not usable, i.e. learners couldn't perform their tasks and assignments successfully, it will be total waste of time and will discourage learners from attending courses. This situation can be avoided if the teachers ensure the achievement of e-learning usability through a priory identification of the learners. The necessary information about student's characteristics could be derived from inquiry [2], teacher's previous experience, pedagogy theory and practice. Taking into consideration the usability research, we can summarize the main learners' characteristics as follows:

- Literacy – computer, domain knowledge;
- Cognitive abilities – educational level, knowledge background, testing ability;
- Personal abilities (personal preferences):
  1. preferred learning style - deductive, inductive, sequential, reflective;
  2. attitude - theoretical or practical and motivation (self definition);
  3. self passing – course of events (tasks, assessments, tests, exams).

According to the proposed adaptation technique the e-learning usability is achieved by producing adaptive learning resources (*what* would be adapted). They have to ensure flexibility and comfort to learners, content understanding, operational performances as well as they enhance the learning process and the users' satisfaction. This goal is achieved by gradually adapting pedagogical approaches, content granularity and functionality (*how* it is to be adapted) to the level of competence and interests of the users i.e. the preferences of a group of users (*what* is the condition it is to be adapted to). Other benefit is that adapted learning resources are useful for a heterogeneous group of users.

Matching the learner's characteristics and preferences with pedagogical strategies and applied educational approaches and tools is at the core of the e-learning usability achievement.

MATHEMATICAL FORMULATIONS AND METHODS

The estimation of the preferences of a group of learners bases on a mathematical approach that concerns the utility theory [6]. The group preferences are reflected by the preferences of a teacher (decision-maker (DM)) for the way of carrying out an educational process. They have to be in harmony with the preferences of learners which the teacher observes during his work. Standard description of the utility function application is presented by Fig.2. There are a variety of possible final results that are consequence of a learner activity determined by an educational objective, i.e. the activity context. A utility function U(.) assesses each of these results. The DM judgment of these results is measured quantitatively by the following formula:

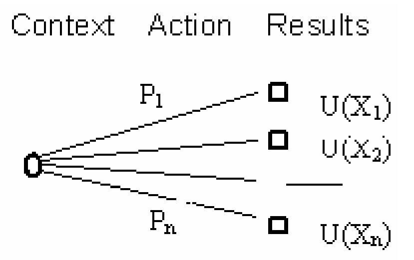

Fig. 2 Utility function application

$$U(p) = \sum_i P_i U(x_i), \quad p \text{ is probability distribution } \sum_i P_i = 1$$

We denote with P_i (i =1÷n) subjective or objective probabilities which reflect the uncertainty of the final results. Strong mathematical formulation of the utility function is the next: Let **X** be the set of alternatives and **P** be a subset of the set of probability distributions over **X**. The DM's preferences over **P** are expressed by ($\succ$), including those over **X**. A utility function is any function u(.) for which is fulfilled:

$$(p \succ q), (p,q) \in \mathbf{P}^2) \Leftrightarrow (\int u(.)dp > \int u(.)dq). \quad (1)$$

The mathematical expectation of the utility u (.) is a quantitative measure concerning the teacher preferences about the probability distributions over **X**. In practice the set **P** is a set of finite probability distribution. We suppose that the singleton distributions belong to **P, (X $\subseteq$ P).** A "lottery" is called every discrete probability distribution over **X**. We mark the lottery "x with probability α and y with probability (1-α)" as $<x,y,\alpha>$. There are different systems of axioms that give satisfaction conditions of utility existence. The most famous of them is the system of **Von Neumann and Morgenstern's axioms** [6].

We start with the assumption that any convex combination of elements of **P** belongs to **P**: (q, p)$\in \mathbf{P}^2 \Rightarrow (\alpha q+(1-\alpha)p)\in \mathbf{P}$, for $\forall\alpha \in[0,1]$ [7, 8]. This condition and **(X$\subseteq$P)** determine the utility function over **X** (when this function exists) with the accuracy of an affine transformation. The most used utility assessment approach is comparisons of the kind: (z ~ $<x,y,\alpha>$), where (x $\succ$ z $\succ$ y), $\alpha\in[0,1]$, $(x,y,z)\in \mathbf{X}^3$. It is well known that the transitivity of "~" is breached in practice because of the so cold *certainty effect* and *probability distortion* identified by Kahneman and Tversky (Prospect Theory) [6]. Here is proposed a procedure which resolves some of these difficulties [7]:

$<x,y,\alpha>$ ($\succ$ or $\prec$ or (~ *or **"no answer"***) z, $\alpha\in[0,1]$, $(x,y,z)\in \mathbf{X}^3$

Every comparison of this kind defines a "learning point" t=(x,y,z,α). With probability $D_1(x,y,z,\alpha)$ the DM assigns the "learning point" to the set A_u or with $D_2(x,y,z,\alpha)$ to B_u: A_u= {(x, y, z, α)/ (αu(x)+(1$-\alpha$)u(y))>u(z)}, B_u= {(x, y, z, α)/ (αu(x)+(1$-\alpha$)u(y))<=u(z)}. The DM answers ($\succ\Leftrightarrow$1; $\prec\Leftrightarrow$ -1; ~ $\Leftrightarrow$ 0) are with probability and subjective uncertainty. ***The main recurrent stochastic procedure in the proposed approach has the form*** [7, 8]:

$$c_i^{n+1}=c_i^n+\gamma_n\left[D'(t^{n+1})-\overline{(c^n,\Psi(t^{n+1}))}+\xi^{n+1}\right]\Psi_i(t^{n+1}),\ \sum_n \gamma_n=+\infty,\ \sum_n \gamma_n^2<+\infty,\ \forall\gamma_n\geq 0. \quad (2)$$

Here $(c^n,\Psi(t))$ denotes scalar product and D'+ξ are the teacher answers ($\succ \Leftrightarrow$ 1; $\prec$ $\Leftrightarrow$ -1; ~ $\Leftrightarrow$ 0) were ξ is noise (uncertainty) in the teacher answers with mathematical expectation equal to zero. The scalar product has the form:

$$(c^n,\Psi(t))=\alpha(c^n,\Phi(x))+(1-\alpha)(c^n,\Phi(y))-(c^n,\Phi(z))=\alpha g^n(x)+(1-\alpha)g^n(y)-g^n(z)=G^n(x,y,z,\alpha). \quad (3)$$

The coefficients c_i^n take part in the decomposition of $g^n(x)$ by a chosen family of functions ($\Phi_i(x)$): $g^n(x)=\sum_{i=1}^{N} c_i^n\Phi_i(x)$. The line above $\overline{T}=(c^n,\Psi(t))$ means that $\overline{T}$ = 1, if T>1, $\overline{T}=-1$ if T<(-1) and $\overline{T}=T$ if -1<T<1. It is known that under the procedure (2) conditions specified above the next integral converges to the (min):

$$J_{D'}(G^n(x,y,z,\alpha))=M(\int_{D'(t)}^{G^n(t)}(\bar{y}-D'(t))dy)=\int(\int_{D'(t)}^{G^n(t)}(\bar{y}-D'(t))dy)dF\xrightarrow[n]{p.p.}\inf_{s(t)}\int(\int_{D'(t)}^{s(t)}(\bar{y}-D'(t))dy)dF. \quad (4)$$

Here p.p. denotes "almost sure" and s(t) denotes s(t)=αs(x)+(1-α)s(y)-s(z). After some calculations the following make the convergence clear:

$$\inf_{s(t)}\int\int_{D'(t)}^{s(t)}(\bar{y}-D'(t))dydF \overset{p.p.}{\geq} \overline{\lim_n}(\frac{1}{2}\int\overline{(G^n(t)}-D'(t))^2dF) \geq 0 \quad (5)$$

Taking in to account the convergence and the structure of the function $G^n(x,y,z,\alpha)$ (3) it is assumed that $g^n(x)$ is approximation of the empirical utility if (*n*) is sufficiently great. The "learning points" are posed with the use of a pseudo-random Sobol's sequences.

AN EXAMPLE OF LEARNERS PREFERENCES ESTIMATION THROUGH A TEACHER

The estimation of the preferences of a group of learners is performed by a decision support system for estimation of individual's utility functions developed on the basis of the presented mathematical formulations and methods in an environment that consists of VISUAL STUDIO, VISUAL BASIC 6.0. The final calculations and graphics are performed with the help of MATLAB.

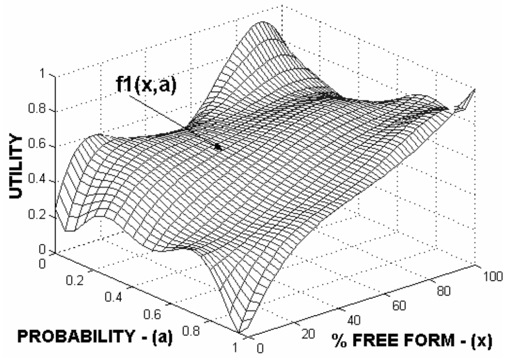

Fig.3 Utility $f_1(x,\alpha)$

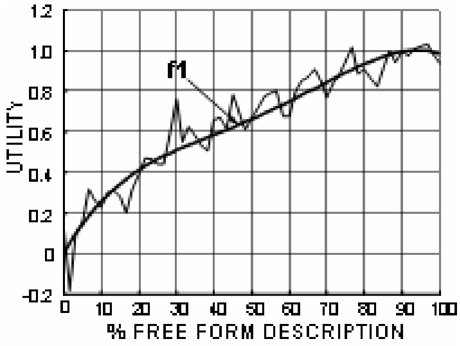

Fig.4 Utility f_1 (x)

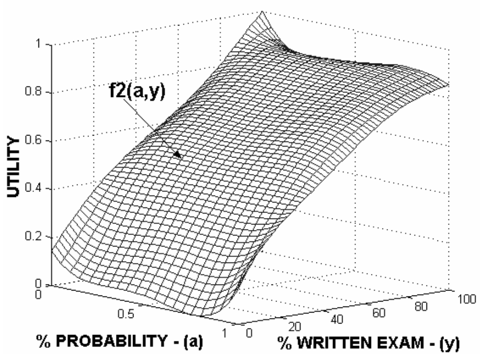

Fig.5 Utility $f_2(x,\alpha)$

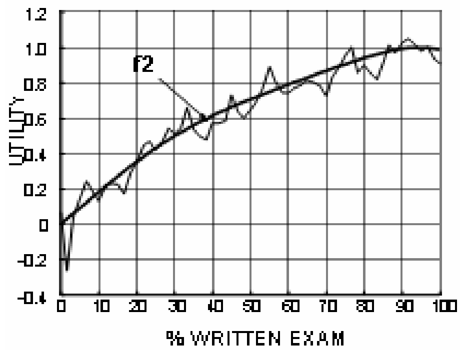

Fig.6 Utility f_2 (x)

The objective of this example is the estimation of the learners' preferences for the examination form and style. This estimation bases on the teacher's opinion of these preferences that is a result of his experience. The form of the examination (A) concerns the way of knowledge expression by a learner: test or free expression. The examination style (B) is presented by the oral and written examination. The possible criteria for the estimation of the preferences of learners which satisfaction is the objective of the teacher during an examination are the followings: (A) "% test in relation to the entire examination material" (0% to 100%) - Fig. 3 and Fig. 4; (B) "% time for written examination in relation to the whole time that is necessary for this examination" (0% to 100%) - Fig. 5 and Fig. 6.

The number of teacher answers is 64 for the Fig.3 and Fig. 4. It is sufficient only for the first approximation. The seesaw lines in Fig.4 and Fig.6 recognize correctly more then 95% of the teacher answers. The utility dependence on probability can be assessed directly with the proposed procedure (2). For this purpose we search for an approximation of the kind u(x, α), $\alpha\in[0,1]$, $x\in\mathbf{X}$ following *Kahneman* and *Tversky*. The utility functions u(x, α) are shown on fig.3 and fig. 5. The explicit formula of the utility u(.) has the form $u(x)=\int_0^1 u(x,\alpha)d\alpha$. Fig 5 and fig. 6 are constructed by 1024 "learning points".

Since the teacher accepts that the factors (A) and (B) are mutual independent in relation to "utility", the utility function has the following expression:

$$U(a,b)=K_1*f_1(a)+K_2*f_2(b)+(1-K_1-K_2)*(f_1(a)*f_2(b)),\quad a,b\in[0,100]\%. \qquad (6)$$

The determination of the coefficients K_1 and K_2 depends on the determination of $f_1(.)$ and $f_2(.)$. This utility function is presented by the Fig. 7 and Fig. 8. The figure 8 presents the lines of identical preferences that show a way for partition the group of learners in subgroups in accordance with their identical preferences. We can determine to which subgroup belongs a learner through the construction of his $f_1(.)$ and $f_2(.)$. They are a source for the determination of a_{max} and b_{max} and $U(a_{max},b_{max})$ that shows the position of the learner in the space presented by figure 8, i.e. the subgroup to which the learner belongs.

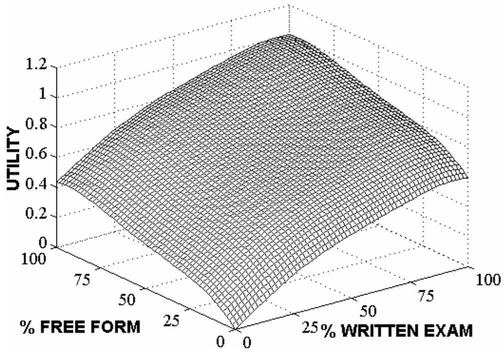

Fig.7 Teacher Utility

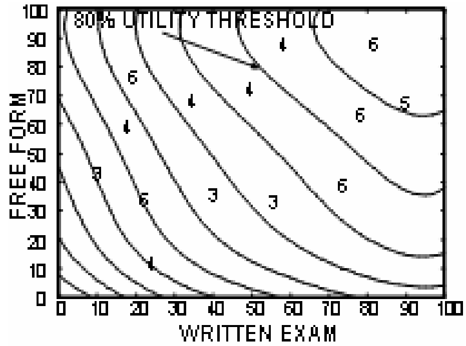

Fig.8 Partition of E-Learner's group

CONCLUSIONS AND FUTURE WORK

The fundamental challenge facing today's learning professionals is the need to meet the educational goals to the needs and preferences of individual learners or group of them. A one-size-fits-all approach does not work well enough. That is why teachers need to provide customized learning experiences for targeted groups. We present an approach to the estimation of learners' preferences that helps teachers to adapt learning resources to the learners. This approach is used in our research for determination of the learning style of learners, although it is also applicable to other learners' preferences, therefore we are going to extend our researches.

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