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CONTRIBUTIONS REGARDING THE EVALUATION AND SELECTION PROCESS FOR VIRTUAL EDUCATIONAL SYSTEMS USING FACTORIAL ANALYSIS

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Complexitatea soluțiilor destinate procesului de instruire electronică a condus la numeroase studii care abordează problematica criteriilor de alegere a unei platforme educaționale. Dintre multitudinea metodelor descriptive de analiza datelor, ținând cont de anumite limitări ale aplicabilității acestora, analiza factorială este tipul de metodă care se potriveşte cel mai bine a fi utilizată în studiul evaluării sistemelor educaționale uniformizate. Lucrarea prezintă aplicabilitatea acestei metode într-un studiu de caz real.

The variety of solutions dedicated to online distance learning lead to many research studies approaching the criteria of selection process for virtual educational systems. There are many descriptive methods for data analysis but considering the special limitations and requirements, the factorial analysis is a method which could serve to an evaluation study for such systems. This paper presents the applicability of this method within a real case study.

Keywords: factorial analysis, ANOVA, evaluation, virtual educational system

Introduction

Based on the research studies done up to date there are a series of observations consisting of advantages and disadvantages of using only the elearning technologies and these are as follows:

- Management learning systems for classic educational solutions do not match to the development of online distance learning systems;
- Traditional educational institutes consider inadequate the solutions of online distance learning systems, so there is a need to allocate new resources for this type of development;

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- The students requirements attending virtual classrooms could be better developed and improved if the educational institution is focused on this solution;
- The characteristics of the target groups are totally different from classic to online distance learning systems;
- The pedagogical issues alternate as well from classic to online distance learning systems;

1. Online distance learning – modes of learning

To understand the capabilities of the various learning management systems, it is useful to distinguish between online *education* (academic institutions) and online *training* (corporate and organizational). Learning objectives for online educational courses tend to cover what students need to know about a subject (*knowledge*), while objectives for online technical training courses tend to cover what students need to be able to do (*skills*) [1].

Online Education – learning management systems implemented at colleges and universities, including organizations that provide professional military education, need to be able to automate administrative services as well as enable pieces of the learning process. Administrative applications for higher education institutions tend to be large, high cost value systems that manage student registration, record keeping, financial aid, scheduling, grants management, library systems and other administrative functions. Due to their size, complexity and reliability, these applications are known as enterprise applications.

Online Training – the automation of administrative services is often less important for training applications, where the focus shifts to applications that enable and manage the learning process. For example, several commercially available learning management systems have built-in software features that are adept at tracking a student's progress to a predetermined learning path [1,2,3].

Within the context of rapid technological change and shifting market conditions, the actual education system is challenged with providing increased educational opportunities without increased budgets. Many educational institutions are answering this challenge by developing distance education programs. At its most basic level, distance education takes place when a teacher and learners are separated by physical distance, and technology (i.e. voice, video, data, and print), often in concert with face-to-face communication, is used to bridge the instructional gap. These types of programs can provide adults with a second chance at a college education, reach those disadvantaged by limited time, distance or physical disability, and update the knowledge base of workers at their places of employment [4,5,6]. The *learning web* was presented by Norrie and Gaines as "*a systemic approach to the modeling and support of knowledge* *processes in a learning society*" [5]. This article addresses the rationale for, and systemic foundations of, the learning web, its implications for restructuring the higher education system, and the role of information technology in supporting that restructuring.

According to many researchers and specialists, virtual educational systems represent the right solution for enhancing the knowledge assimilations by the students and as well as for emphasizing the development financial potential of an educational institute/ organization or training company.

After a research report by Lori Mitchell, elearning courses add value to traditional learning modes by offering self-paced or live, instructor-led classes [1]. Specifically, self-paced courses can be taken at the student's leisure and are good for self-motivated students. According to Mitchell, there are some conclusions concerning the implementation of the modes of elearning into corporate training programs see table 1).

Table 1.

Modes of learning

Modes of learning	Strengths	Ideal for:
Traditional classroom (Classic learning support)	Fan interaction Physical instructor Set time and place	Collaboration Leadership skills Team building Management skills
Self paced elearning (CD-ROM support)	Highly flexible Low cost Rapid pace	Self motivation Remote employees IT training Technical material
Live, instructor-led elearning, virtual seminars (Virtual collaboration)	Real time interaction Low cost Recordable	Remote employees Management skills Leadership skills

The development of a solution suitable for virtual education must take into consideration the issues presented above. To start-up such a project involves some uncontrolled risks. A technical solution could not be suitable to an organization and/or to its potential users. That could involve both financial loses and psychological reservations into developing other solutions.

Meanwhile the elearning solutions start to be developed and implemented very fast in Romania. For this reason, it is required to develop an evaluation methodology for virtual educational systems. By taking into consideration the economic aspects, the selection and adoption of such a system requires an analysis of its competences focused on three main factors: infrastructure, learning content and related educational services.

ANOVA factorial analysis (analysis of variance) represents a statistic tool used for data analysis. ANOVA methods emphasize, for example, the homogeneity (or un-homogeneity) of some measurable features, the procedures of multi-comparison analysis detecting the related factors [7,8,9].

Using the variance analysis it can be simultaneously determined the influence of two or more independent variables upon a dependent one. There are many advantages using this study for experimental researches. The first benefit of this method is the efficiency of the study because two or more independent variables are simultaneous analyzed, getting information regarding each factor, their influence and interaction between them.

2. Contributions regarding the methodology for evaluation and selection process of an elearning solution within educational market

The case study presented below emphasizes the applicability of descriptive methods for organizing, analyzing and interpretation of data necessary to develop an evaluation methodology for elearning solutions within educational market. The conclusions of the researches done before, the social-economic and psychological factors (growth of the access to Internet, development of new information technologies, emergence of modern concepts, change management attitudes) – all served to the development of this case study.

The main objective is to find an optimal solution of a possibility for the development of new elearning solutions considering the following aspects: the solution must be credible and must fit within the existing range of solutions; the solution must ask to the technical specifications related to the final user; the solution must allow to be further developed according to the area of interest where it is applied.

A market survey analysis is required in order to develop optimal solution for each well-defined market segment. That shall be done using the method for investigation of representative elements within a group of study. For this reason, in this case study, there are considered the following main groups of study:

- Training companies (or training departments within companies);
- Academic field (universities).

These groups are split into four homogenous groups, as it follows:

- Training companies during year 2000 (I_1),
- POLITEHNICA University of Bucharest during year 2002 when FAVIR project was completed (I_2),
- POLITEHNICA University of Bucharest during year 2005 (I_3),
- POLITEHNICA University of Bucharest during year 1999 when FAVIR project was started (I_4).

Table 2.

The results of the interviews (average marks awarded)

Solution / Groups of study	M_1	M_2	M_3
	CD-ROM Training Support	**Online Collaboration**	**Complex Solution (combined)**
I_1	5	1	3
I_2	1	6	5
I_3	7	8	3
I_4	7	5	9

On time scale based, all these groups have been interviewed regarding the potential solutions dedicated to them. So the solutions presented to them are as follows:

- CD-ROM training support including courses and self-paced educational content (M_1),
- Live, instructor-led elearning, virtual seminars and online collaboration including audio-video and multimedia features (M_2),
- A complex solution, combining the features presented above (M_3).

Based on preference, each group gave marks to the solutions presented. The mark scale is from 1 (poor solution) to 9 (best solution). The results are centralized in table 2. Using this data collection and based on analysis of variance it can be determined the optimal solutions suitable to each group of study. For this reason there are seven steps to be followed:

1. Calculation of the gravity center of the studied elements (table of values);
2. Finding the origin of the studied elements and fixing the gravity center;
3. Matrix calculation for variance – covariance;
4. To diagnose the variance – covariance matrix;
5. To analyze the individual points on the main axes;
6. To analyze the important points on the main axes;
7. Graphical plotting of the points within the two main axes plan

The results presented in table 2 represent the values of the following matrix:

$$M_{(3,4)} = \begin{pmatrix} 5 & 1 & 3 \\ 1 & 6 & 5 \\ 7 & 8 & 3 \\ 7 & 5 & 9 \end{pmatrix}. \qquad (1)$$

All the seven steps presented above must be solved by using specialized software, but for a better understanding of the methodology, these steps are described in briefly below.

Step 1. Calculation of the gravity center (G) of the studied elements – calculation of the three components (x,y,z) within $\left(R^3\right)$:

$$x = \frac{5+1+7+7}{4} = 5;$$
$$y = \frac{1+6+8+5}{4} = 5; \qquad (2)$$
$$z = \frac{3+5+3+9}{4} = 5.$$

Step 2. Finding the origin of the studied elements and fixing the gravity center - columns subtraction from each element *x*, *y* şi *z*:

$$X = \begin{pmatrix} 0 & -4 & -2 \\ -4 & 1 & 0 \\ 2 & 3 & -2 \\ 2 \quad 0 \quad 4 & & \end{pmatrix}. \qquad (3)$$

Step 3. Variance – covariance matrix calculation, (*V*); it is done by using transpose $\left(X^{'}\right)$ of matrix (*X*):

$$V = \frac{1}{n} \cdot X^{'} \cdot X, \qquad (4)$$

$$X^{'} = \begin{pmatrix} 0 & -4 & 2 & 2 \\ -4 & 1 & 3 & 0 \\ -2 & 0 & -2 & 4 \end{pmatrix}, \qquad (5)$$

where n represents the number of studied groups (in this case *n=4*).

Step 4. Diagonalising the matrix *V*.

There is:

$$V * \bar{H} = \bar{H}, V * \bar{H}_1 = \bar{H}_2, V * \bar{H}_2 = \bar{H}_3, \cdots, V * \bar{H}_{k-1} = \bar{H}_k. \qquad (6)$$

Iterative calculation of the above vectors leads to convergence towards first latent vector $\vec{U}_1$ having latent value λ_1. The calculation is as follows:

a) $$I = \frac{1}{n}\left[24 + 26 + 24\right] = 18.5 \qquad (7)$$

where 24,25,26 are the main elements of main diagonal of matrix V;

b) Changing the origin:

$$\det\left(V - \lambda I\right) = 0, \qquad (8)$$

where λ are latent values of matrix *V* and *I* is the unit matrix.

$$\det\left[\frac{1}{4}\begin{pmatrix}24 & 2 & 4\\ 2 & 26 & 2\\ 4 & 2 & 24\end{pmatrix} - \lambda\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{pmatrix}\right] = 0 \tag{9}$$

$$\det\left[\frac{1}{4}\begin{pmatrix}24-4\lambda & 2 & 4\\ 2 & 26-4\lambda & 2\\ 4 & 2 & 24-4\lambda\end{pmatrix}\right] = 0, \tag{10}$$

So, there are three different latent values as follows:

$$30 - 4\lambda_1 = 0 \Rightarrow \lambda_1 = \frac{30}{4} = 7{,}5 \tag{11}$$

$$24 - 4\lambda_2 = 0 \Rightarrow \lambda_2 = \frac{24}{4} = 6 \tag{12}$$

$$20 - 4\lambda_3 = 0 \Rightarrow \lambda_3 = \frac{20}{4} = 5. \tag{13}$$

Verifying:

$$\lambda_1 + \lambda_2 + \lambda_3 = I, \tag{14}$$

$$7.5+6+5=18.5. \tag{15}$$

Each latent vector has attached a latent value, and this value represents the inertia of the numbers of points on this direction. In our case, first axis (attached the highest latent value (λ_1=7.5), representing 40.5% from total inertia). The first plan, described by the first two axes shall be generated by the difference (18.5-3.5= 15) representing 73% from total inertia.

c) Analyzing the latent vectors, attached to the latent values. Each value of λ, shall be replaced as follows:

$$V\vec{u} = \lambda_i \vec{u}_i , \tag{16}$$

where $\vec{u}_i$ - latent vector attached to latent value λ_i; $\vec{u}_i$ having the coordinates (a,b,c).

$$V \cdot \vec{u} = \frac{1}{4}\begin{pmatrix}24 & 2 & 4\\ 2 & 26 & 2\\ 4 & 2 & 24\end{pmatrix} \cdot \begin{pmatrix}a\\ b\\ c\end{pmatrix} = \lambda \begin{pmatrix}a\\ b\\ c\end{pmatrix} \tag{17}$$

$$\begin{cases}\frac{1}{4}[24a + 2b + 4c] = \lambda \cdot a\\ \frac{1}{4}[2a + 26b + 2c] = \lambda \cdot b\\ \frac{1}{4}[4a + 2b + 24c] = \lambda \cdot c\end{cases} \quad \begin{cases}\frac{1}{4}(24a + 2b + 4c) = 7{,}5 \cdot a\\ \frac{1}{4}(2a + 26b + 2c) = 7{,}5 \cdot b\\ \frac{1}{4}(4a + 2b + 24c) = 7{,}5 \cdot b\end{cases}. \tag{18}$$

If $\lambda_j = 7{,}5 \Rightarrow$ for the first latent vector, the solution of this system shall be the coordinates of latent vector $\vec{u}_1$:

$$\begin{cases} a = 1 \\ b = 1 \Rightarrow \vec{u}_1 = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \\ c = 1 \end{cases} \cdot \qquad (19)$$

If $\lambda_2 = 6 \Rightarrow$

$$\begin{cases} \frac{1}{4}(24a + 2b + 4c) = 6 \cdot a \\ \frac{1}{4}(2a + 26b + 2c) = 6 \cdot b \Rightarrow \\ \frac{1}{4}(4a + 2b + 24c) = 6 \cdot c \end{cases} \qquad (20)$$

So, the system solutions are:

$$\begin{cases} a = 1 \\ b = -2 \Rightarrow \vec{u} = \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix} \\ c = 1 \end{cases} \cdot \qquad (21)$$

The vectors $\vec{u}_i$ are normed according to the formula:

$$\|\vec{u}\| = \sqrt{a^2 + b^2 + c^2}\ , \qquad (22)$$

where

$$\vec{u} = \begin{pmatrix} a \\ b \\ c \end{pmatrix} \cdot \qquad (23)$$

So:

$$\vec{u}_1 = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \Rightarrow \|\vec{u}_1\| = \sqrt{1^2 + 1^2 + 1^2} = \sqrt{3}; \qquad (24)$$

$$\vec{u}_2 = \begin{pmatrix} 1 \\ -2 \\ 1 \end{pmatrix} \Rightarrow \|\vec{u}_2\| = \sqrt{1^2 + (-2)^2 + 1^2} = \sqrt{6}; \qquad (25)$$

$$\vec{u}_3 = \begin{pmatrix} -1 \\ 0 \\ 1 \end{pmatrix} \Rightarrow \|\vec{u}_3\| = \sqrt{(-1)^2 + 0^2 + 1^2} = \sqrt{2}. \qquad (26)$$

The normed vector $\widetilde{u}_1$ shall be the vector u_i divided by its norm:

$$\widetilde{u}_1 = \begin{pmatrix} \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} \end{pmatrix},\ \widetilde{u}_2 = \begin{pmatrix} \frac{1}{\sqrt{6}} \\ \frac{-2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} \end{pmatrix},\ \widetilde{u}_3 = \begin{pmatrix} \frac{-1}{\sqrt{2}} \\ 0 \\ \frac{1}{\sqrt{2}} \end{pmatrix} \cdot \qquad (27)$$

d) Calculation of latent vectors and their values by iteration $V \cdot \overline{H} = \overline{H}_1; V \cdot \overline{H}_1, \ldots\ldots, V \cdot \overline{H}_n = \overline{H}_{n+1}, ..$ where $\overline{H}$ is an arbitrary vector.

The vector range $\overline{H}_1, \overline{H}_2, ..., \overline{H}_n, ..,$ has the property of convergence towards first latent vector U_1 (attached to the highest latent value λ_1). For this reason it is easy to calculate $\overline{U}_1$, and then $\overline{U}_2$ and so on.

The calculation of the basic coordinates on main axes Δ_α (generated by latent vectors U_α) are resulting by multiplying matrix X and U_α. So,

$$\begin{pmatrix} 0 & -4 & -2 \\ -4 & 1 & 0 \\ 2 & 3 & -2 \\ 2 & 0 & 4 \end{pmatrix} \cdot \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{-3}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \end{pmatrix} = \begin{pmatrix} \frac{-6}{\sqrt{3}} & \frac{6}{\sqrt{6}} & \frac{-2}{\sqrt{2}} \\ \frac{-3}{\sqrt{3}} & \frac{-6}{\sqrt{6}} & \frac{4}{\sqrt{2}} \\ \frac{3}{\sqrt{3}} & \frac{-6}{\sqrt{6}} & \frac{-4}{\sqrt{2}} \\ \frac{6}{\sqrt{3}} & \frac{6}{\sqrt{6}} & \frac{2}{\sqrt{2}} \end{pmatrix} \begin{matrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{matrix}. \tag{28}$$

For example, the coordinates of I_1 are as follows:

- for the first main axis $-\frac{6}{\sqrt{3}}$; for the second one $\frac{6}{\sqrt{6}}$; for the third one $-\frac{2}{\sqrt{2}}$.

Analysis of the basic points on the main axes. In order to obtain the coordinates for the projections of the initial variables (the basic points) within the new coordinate system, it is necessary to multiply the vectors $\vec{U}_1$, $\vec{U}_2$ and $\vec{U}_3$ by a scalar term. So the matrix in formula 29 shall suffer the following changes: first column shall be multiplied by $\sqrt{\lambda_1}$ ($\sqrt{7{,}5}$); second column shall be multiplied by $\sqrt{\lambda_2}$ ($\sqrt{6}$); third column shall be multiplied by $\sqrt{\lambda_3}$ ($\sqrt{5}$).

$$\begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} \end{pmatrix} \leftarrow M \tag{29}$$

It results:

$$\begin{matrix} M_1 \rightarrow \\ M_2 \rightarrow \\ M_4 \rightarrow \end{matrix} \begin{pmatrix} \sqrt{\frac{7,5}{3}} & \sqrt{\frac{6}{6}} & -\sqrt{\frac{5}{2}} \\ \sqrt{\frac{7,5}{3}} & \frac{-2\sqrt{6}}{\sqrt{6}} & 0 \\ \sqrt{\frac{7,5}{3}} & \sqrt{\frac{6}{6}} & -\sqrt{\frac{5}{2}} \end{pmatrix} \Leftrightarrow \begin{pmatrix} \sqrt{\frac{5}{2}} & 1 & -\sqrt{\frac{5}{2}} \\ \sqrt{\frac{5}{2}} & -2 & 0 \\ \sqrt{\frac{5}{2}} & 1 & \sqrt{\frac{5}{2}} \end{pmatrix} \quad (30)$$

Graphical representation within the plan of main axes. Figure 1 presents two axes orthogonal system(Δu_1) and(Δu_2), the main points being figured on it (I_1, I_2, I_3 şi I_4).

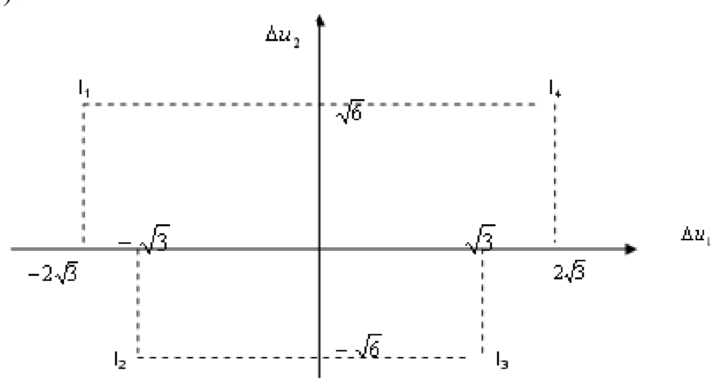

Fig. 1. Graphical representation within the plan of main axes

In this case, there will be obtained the main values and the values of the individual points for each axis presented in table 3.

Table3 .

Values of main coordinates (the solutions) (groups of study)

	Axis Δu_1	**Axis** Δu_2	**Axis** Δu_3
I_1	$-\frac{6}{\sqrt{3}}$	$\frac{6}{\sqrt{6}}$	$-\frac{2}{\sqrt{2}}$
I_2	$-\frac{3}{\sqrt{3}}$	$-\frac{6}{\sqrt{6}}$	$\frac{4}{\sqrt{2}}$
I_3	$\frac{3}{\sqrt{3}}$	$-\frac{6}{\sqrt{6}}$	$-\frac{4}{\sqrt{2}}$
I_4	$\frac{6}{\sqrt{3}}$	$\frac{6}{\sqrt{6}}$	$\frac{2}{\sqrt{2}}$

Conclusions

The final conclusions and the analysis of the results presented above could be summarized as follows:

- for the first axis there are two different directions: the group I_1 (training companies 2000) and I_4 (UPB 1999) share the same preferences having the highest absolute coordinates; contrary, same groups have same influence on axis 2 with the other groups (absolute values are equal) – interpretation of this conclusion consisting of an important change of opinion related to online distance learning at academic level;
- during the period 1999-2000 the distance learning solutions were focused on supplying CD support for a variety of courses, the same solution being shared between universities and training companies; the training companies have chosen this approach because of time, money, clients (being easier to train a client in order to correctly use a product or a service; universities (UPB) have chosen this solution because of mentality of both students and teachers, but the elearning implementation process has its development start during this period;
- the results obtained using the factorial analysis are useful in the development of more complete analysis and studies related to evaluation process of educational solutions dedicated to online distance learning;
- The main objective of this study was to scientifically determine the following aspects:
  - Development of new solutions by considering an educational market survey using the method for investigation of representative elements within a group of study;
  - Development of a methodology used for analysis, evaluation and selection of an optimal educational solution dedicated to a specific user / group of users/ institution or company;
  - Identifying of adequate methods dedicated to educational marketing;
  - Development of the training process within engineering area using new and modern virtual technologies.

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