SCIENTIFIC
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System structure for online education process at higher education institutions

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ABSTRACT:

The document presents the online learning process as a system containing: the education operator, the product – equivalent to the quality of learning and losses representing weaknesses and defects. The system is represented by three vectors, namely the education operator vector, the product vector and the loss vector. The vector representation of the system provides the possibility of quantitative description of its operation and confirms the metrisability of the online learning process at different types of universities. The model presented can be used as a tool for analysing and evaluating online learning processes at universities with different fields of study.

Struktura systemowa procesu kształcenia online w szkołach wyższych

Słowa kluczowe: kształcenie online, e-edukacja, jakość kształcenia, wektorowa reprezentacja systemu, kształcenie zdalne

STRESZCZENIE:

W publikacji przedstawiono proces kształcenia online jako system zawierający: operator edukacji, produkt – utożsamiany z jakością kształcenia oraz straty oznaczające słabości i wady. System ten jest reprezentowany trzema wektorami, tj. wektorem operatora edukacji, wektorem produktu i wektorem strat. Wektorowa reprezentacja systemu daje możliwość ilościowego opisu jego działania i stanowi o metryzowalności procesu kształcenia online na uczelniach różnego typu. Pokazany model może być wykorzystany jako narzędzie analizy i ewaluacji procesów kształcenia online w uczelniach z różnymi kierunkami nauczania.

1. INTRODUCTION

High quality of learning is one of the core priorities of the European Union [1]. A dynamic development of e-learning has recently been observed which is inseparably linked to the effectiveness of e-education and the methods of its metrisability. This is accompanied by the use of modern information and communication technologies and the reasonable organisation of material facilities as well as teaching and competent evaluation. The use of system engineering makes it possible to answer "measurably" fundamental questions concerning the process objective, its duration and location, personnel qualifications, efficiency assessments, measures and other diverse additional learning activities [2]. At the same time mathematical models of system engineering allow for the development of multi-criteria indicators and their use to optimise subsequent organisational and other steps [3].

Considering the capabilities of system engineering [4], this study proposes a system structure model that can serve as a tool for analysing and evaluating the online learning process at any university. The system analysis of the online learning process allows quantitative relations between the impact of batch streams, the quality of education and losses to be formulated. Online learning is understood as: distance learning courses, online courses, synchronous online courses, online programmes, e-learning, etc.

The study shows a concept of using the engineering of online learning systems over time which allows the process to be described with the following vectors:

- distribution vector of batch streams $\vec{O}$,
- product vector $\vec{P}$
- and loss vector $\vec{S}$.

Relations of the following vectors: $\vec{O}$, $\vec{P}$ i $\vec{S}$, and reflect the simultaneity and ambiguity of the system operation which symbolically presents the following relations between the education operator $\widehat{O}_e$, the product operator $\widehat{P}$ and the loss operator $\hat{S}$:

$$\widehat{O}_e \text{ [batch streams]} \rightarrow \widehat{P} + \hat{S}. \quad (1)$$

The relation (1) and the diagram of the system structure are illustrated in Figure 1. The literature of the subject [5] lacks a proposal for an e-education analysis based on the theory of engineering systems.

2. E-EDUCATION PROCESS SYSTEM STRUCTURE

An example image of the system adopted for further analysis is shown in Figure 1.

The metrisability of this part of the system which is responsible for distributions of stream outputs, quality of education (product) and losses following the adoption of the concept of the education model are exmained below. The concept is developed by the university in line with its policy, mission, vision and management strategy.

Four material resource streams, four information resource streams and two control resource streams flow into the area of the education operator $\widehat{O}_e$ identified as the product manufacturing operator. The material resources include: the energy stream, the stream of technical infrastructure (e.g. transmission and reception infrastructure), the material preparation stream and the financial stream. Information resources include: employee training stream, educational content stream, learning process flow and output control stream. The control streams contain the stream of activities over time and the process dynamics variation stream (corrections).

Each of these streams represents the number of actions appropriate to its nature in time. The types of activities of the different streams determine the purpose of the system which depends on the type of university and the field of study. The entire set of streams feeding the system represents the vector $\vec{O}$ which is the vector sum of the individual batch vectors: this is explained in Figure 1 and Figure 2. The actions of the education operators $\widehat{O}_e$ give the product $\widehat{P}$ and the losses $\hat{S}$. The actions of the product operator $\widehat{P}$ is identified as the effectiveness of learning and is represented by the vector $\vec{P}$. Components of the product vector (e-learning efficiency) $\vec{P}$ represent: knowledge, skills, social competences, space and time flexibility, options for selecting topics, a questionnaire for evaluating the quality of learning and other features. The entire set of actions of the product operator $\widehat{P}$ is represented by the vector $\vec{P}$, which is the vector sum of the individual vectors of the component activities. This is shown in Figure 1 and Figure 2.

[1] See: Ibid., items 1–3.
[2] See: Bibliography, items 1–5.
[3] See: Ibid., items 1–3.
[4] Ibid.
[5] See: Ibid., items 4–5.

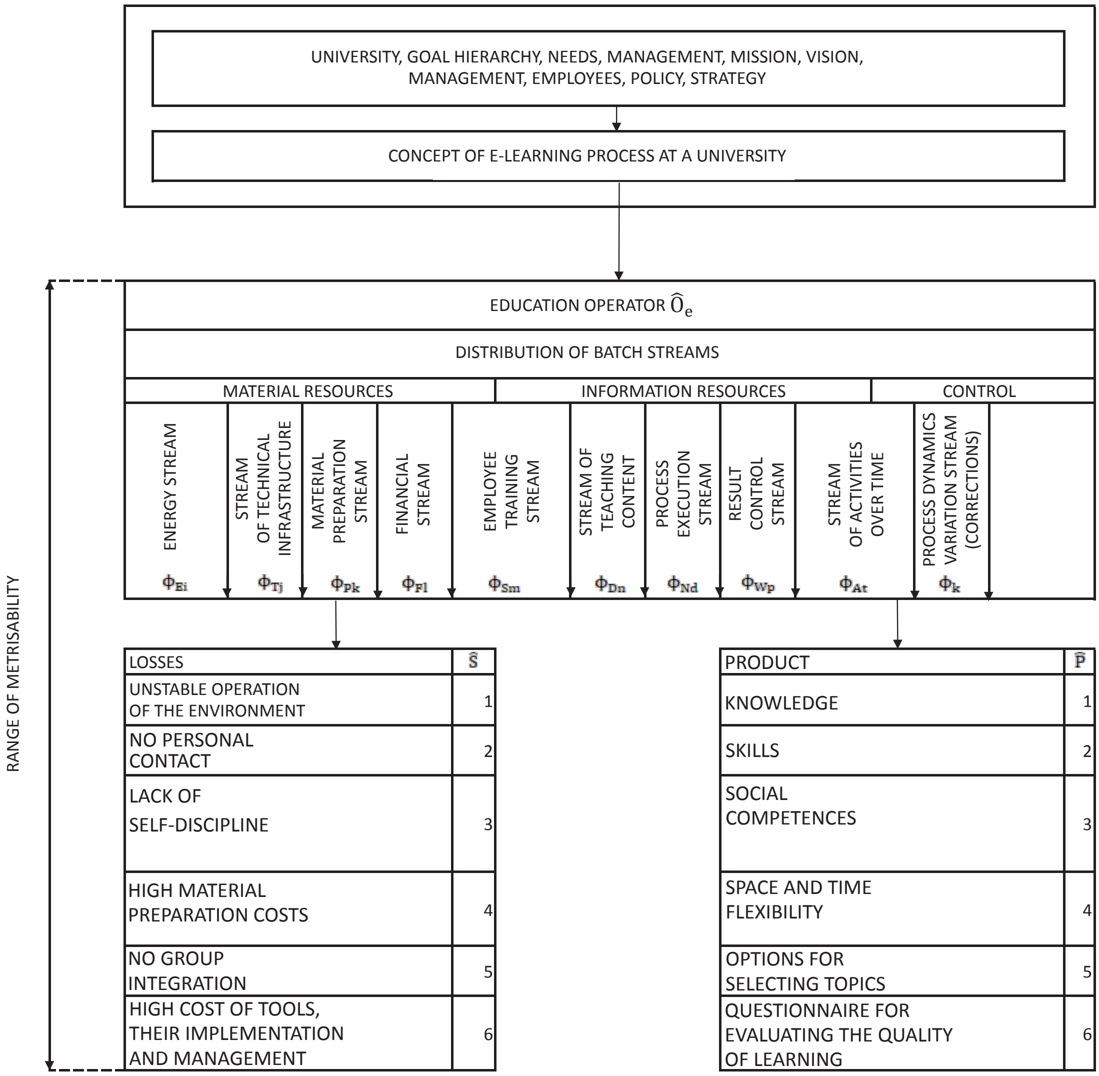

Figure 1 Schematic diagram of the system of the online learning process at universities (own study)

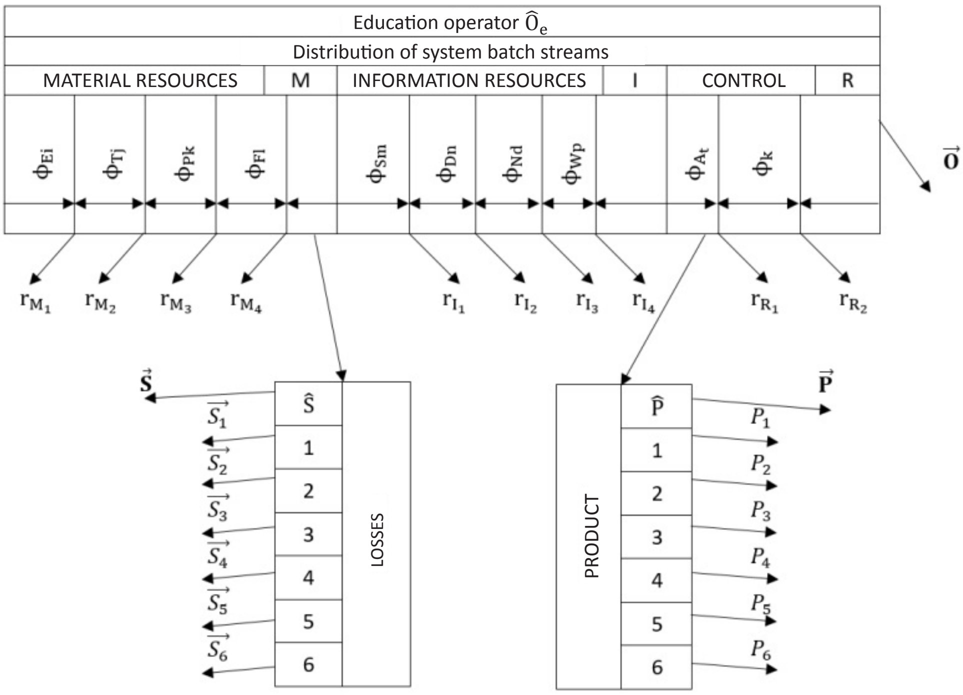

Figure 2 Vector representation of the online learning process at universities (own study)

The actions of the e-learning education operators $\widehat{O}_e$ also create unavoidable losses, as indicated by the operator $\widehat{S}$ (Fig. 1). The losses include: unstable work of the environment, no personal contact, lack of self-discipline, no group integration, high costs of material preparation and high cost of tools, their implementation and management. The actions of the losses $\widehat{S}$ are represented by the vector $\vec{S}$ which is the vector sum of the vector components representing the above-mentioned number of weaknesses and defects in the e-learning system. This is illustrated in Figure 1 and Figure 2. According to the presented approach, the e-learning system is the intended action of the operator $\widehat{O}_e$ in response to the batch streams expressing a set of relations between their components which leads to a certain efficiency of learning $\widehat{P}$ and unavoidable losses $\widehat{S}$.
In the system all relations are active, i.e. each relation has specific tasks. For this reason, a metrisable description of the entire system must include the simultaneous and unambiguous link between the education vector $\vec{O}$, the product vector $\vec{P}$ and the loss vector $\vec{S}$. A precise description of such a relation is extremely difficult and, in some cases, immeasurable. Some possibilities, however, are available if vector and scalar functions are used.

3. ONLINE LEARNING SYSTEM VECTORS

3.1 Initial remarks

All vectors of the online learning system are expressed in a rectangular coordinate system (Fig. 3, 4, 5). The values of weights of individual vectors are marked on the *x* axes of the system. In any case the sum of the weights of all vectors corresponding to one part of the system is equal to one hundred percent or one. The values of modules of individual vectors of the system are marked on the *y* axes.
The values of the products, vectors and weights are dimensionless. The unit vector $\vec{e}_x$ corresponds to the *x* axis, whereas the vector $\vec{e}_y$ corresponds to the *y* axis, therefore each of the system vectors takes the form of:

$$\vec{a} = a_x \vec{e}_x + a_y \vec{e}_y . \qquad (2)$$

The values a_x and a_y are between zero and unity:

$$a_x \in [0,1] \qquad a_y \in [0,1] \qquad (3)$$

Each vector of the system has values of modules and weights mapped in a numerical set [0, 1].

The resultant vectors $\vec{O}$, $\vec{P}$ and $\vec{S}$ have modules in the range [0, 1] and their weights are equal to one (Fig. 3, 4, 5).

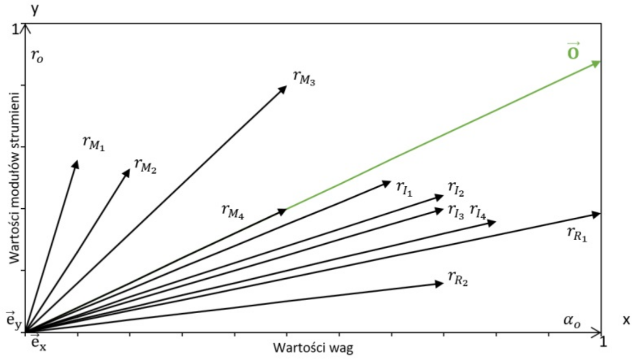

Figure 3 Components of the education (generation) operator vector $\vec{O}$ in the system of values of their modules and weights (own study)

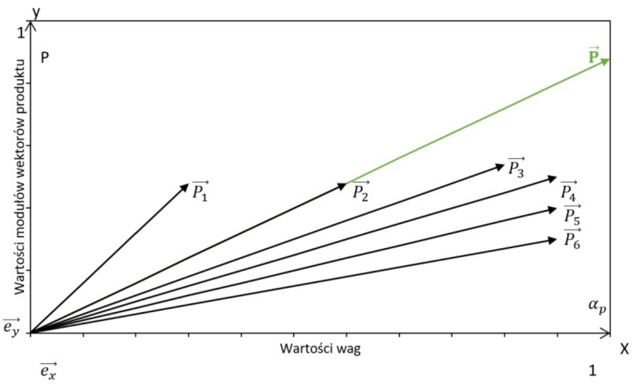

Figure 4 Components of the product vector $\vec{P}$ in the system of values of their modules and weights (own study)

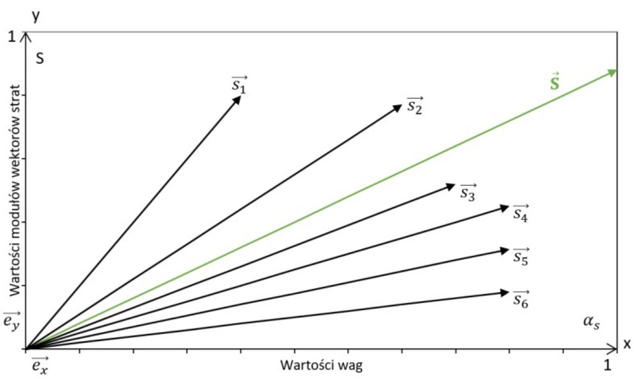

Figure 5 Components of the loss vector $\vec{S}$ in the system of values of their modules and weights (own study)

3.2 Determination of system vectors

In the case of batch stream vectors, their modules constitute the relations of actual output quantities of streaming member elements to the same magnitudes as established by the product concept standard. They will be dimensionless values defining the actions of the streams in time $t_o \leq t \leq t_{fin}$. The values of these magnitudes are marked as a_y in the formula (3). For example, for the energy stream φ_{Ei} (Fig. 1), the dimensionless instantaneous stream output is calculated according to the formula:

$$r_{M_1} C + J = \frac{\int_{t_0}^{t_{fin}} \phi_{E_i}^{rz}(t)\, dt}{\int_{t_0}^{t_{fin}} \phi_{E_i}^{n}(t)\, dt}. \quad (4)$$

The dimensionless outputs for the remaining batch streams are determined in a similar manner. The defined dimensionless stream outputs over time can be determined experimentally during the course of the process. After taking into account the formulas (2) and (4), the following formula for the vector of the energy stream $\overrightarrow{r_{M_1}}$ is derived:

$$\overrightarrow{r_{M_1}} = \alpha_o \overrightarrow{e_x} + r_{M_1}(+)\overrightarrow{e_y}. \quad (5)$$

The batch stream vector components are illustrated in Figure 3. The resultant of the vectors of the stream $\vec{O}$ is the sum of the component vectors.
The product identified as learning efficiency is determined using six vectors. For example, the vector representing knowledge is:

$$\overrightarrow{P_1} = \alpha_p \overrightarrow{e_x} + P_1 \overrightarrow{e_y}. \quad (6)$$

The magnitude α_p is of weight importance, whereas $\overrightarrow{P_1}$ is the module determined by the tests during the results check. The resultant of the vector $\vec{P}$ is the vector sum of the components representing learning efficiency. This is explained in Figure 4 and Figure 5.
The system losses related to the weaknesses and defects of the e-learning system are represented by the vector $\vec{S}$. For instance, losses depicting unstable operation of the environment are represented by the vector $\overrightarrow{S_1}$ as:

$$\overrightarrow{S_1} = \overrightarrow{e_x}\alpha_s + S_1 \overrightarrow{e_y}, \quad (7)$$

where α_S is the weight and S_1 is the module. The values of the component modules of the vector $\vec{S}$ are determined during the evaluation process according to the procedures adopted specifically for the type of tests. The resultant of the vector $\vec{S}$ is the vector sum of the components of the operator vector $\hat{S}$.

4. METRISABLE DESCRIPTION OF THE ONLINE LEARNING SYSTEM

A comprehensive, metrisable analysis and assessment of the system under consideration are possible, provided that its mathematical model is obtained. It should be a scalar or vector relation between the vectors $\vec{O}$, $\vec{P}$ and $\vec{S}$ in a given e-learning model (vectors $\vec{O}$, $\vec{P}$ and $\vec{S}$ represent the process status). Several proposals are possible here. The important proposals will be the ones leading to a better understanding of the phenomena and their optimisation. For example, the following vector relation may be suggested:

$$\vec{J} = \left(\vec{O} \times \hat{P}_7\right)\left|\vec{S}\right| \quad (8)$$

or a scalar relation may be suggested in the following form:

$$L = \left|\vec{O}\right|\left|\vec{P}\right|\left|\vec{S}\right| \quad (9)$$

There are several combinations of different activities on the set of the vectors: $\vec{O}$, $\vec{P}$ and $\vec{S}$.

5. DISCUSSION AND CONCLUSIONS

The study shows new proposals for the analysis and evaluation of the online learning system using the vector system structure. The system consists of an education operator the activities of which result in a product (learning efficiency and losses). The education operator $\hat{O}_e$ impacts the resource, information and control streams. The production operator $\hat{P}$ may be equivalent to learning efficiency, while the loss operator $\hat{S}$ identifies the system weaknesses and defects.
The system is represented by the three vectors: $\vec{O}$, $\vec{P}$ and $\vec{S}$. Appropriate relations between these vectors may serve as a mathematical model for the e-education process. Nevertheless, this is a very difficult task and requires extensive, complex research and thorough analysis of the phenomena accompanying all types of education.
The presented model is not limited by the type of university and the field of study – it can be used in different types of training and schools. Together with its vector representation, it can be an effective tool to analyse and evaluate learning efficiency in the e-education process.

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