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DEVELOPMENT OF METHODOLOGY FOR SUCCESSFUL REALIZATION OF THE TEACHING PROCESS

Abstract: This paper presents the development of a methodology for successful realization of the teaching process and an example of its application in ICS area of Information Technology (IT), ICS1 = 35 whereby ICS areas are assigned measurable quantitative indicators of innovation. The study presents the research results of the innovation intensity of knowledge which are highly significant for teaching process quality improvement on the ISO and SRPS platforms. At the very beginning of every teaching process there is a need to select suitable methods for performing teaching in such a way that it is in accordance with objectives of that teaching process. In addition, the teaching process can be maximally adjusted – or kept unchanged, as much as possible – in accordance with numerous intrinsic and extrinsic factors such as: students' basic pre-knowledge and motivation, their both general and specific abilities (space, library and other facilities), as well as the application of IT. The results of continuous innovation and the determination of innovation in teaching process have been focused on in the examples of area IT. In this paper, a model for the assessment of the effectiveness of a teaching method has been given based on measuring students' previous knowledge. If several different methods of realization can be applied in a teaching process, then a possibility to perform the assessment for each of these methods, prior to the beginning of the teaching process, is viable. In this manner, a methodology that yields good results at the end of teaching process, viewed from aspect of knowledge acquired by students, can be determined.

Keywords: development, methods, teaching process, knowledge, measurement, grading, ICS, IT.

1. INTRODUCTION

Ranking within a wide range of creativity areas, depending on the degree of innovation, brings forth clear indicators and the need for knowledge innovation for target knowledge base and knowledge base system. This study presents the results of the study of the innovation intensity of knowledge, highly significant for teaching process quality improvement on the ISO and SRPS platforms (Institute

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for Standardization of Serbia 2017). In organizing teaching Information technology (IT) is used, as well as the appropriate selection of teaching methods, including teaching facilities and materials.

Quality of teaching greatly depends on the chosen combination of teaching methods. Successful realization of the teaching process fully relies on the specificities of the teaching process, i.e. one or more teaching methods precisely defined for each class. The selection of the teaching methods to be used in a teaching process is largely governed by the preset goal or the objective, as well as on many other extrinsic and intrinsic factors. Some of the basic factors that determine the teaching methods to be used are elementary pre-knowledge of students, classroom facilities, students' motivation, etc. Oral method (method of monologue), method of conversation (method of dialogue), method of working with text in teaching IT, illustrative-demonstrational teaching method, cybernetic teaching methods in teaching informatics, distance learning teaching method are some of the teaching methods commonly used. Although these methods are well known in pedagogical literature (Voskresenski, Glušac 2007), some of them will be briefly presented here given that they are frequently challenged under different circumstances among the academia (some of those views are also presented here).

The method of oral presentation has prevailed to date as an indispensable method of teaching. There is a pervasive perception of this method as one of particular importance in the initial phases of teaching, especially in the absence of students' basic pre-knowledge of subject matter worked on, i.e. this method is particularly effective when students need to be introduced into the learning content they have very little pre-knowledge about. The positive aspect of this method is that the lecturer, familiar with the ICT content, ensures that their students acquire relevant information from the presented subject matter by emphasizing and summarizing crucial points (Holper, et al. 2013). On the other hand, this approach exhibits some inherent weaknesses as well, such as insufficient activity or participation of all students, possibility that students will take lecturer's words for granted and will simply try to memorize and reproduce their words without dwelling deeply into the meaning, i.e. without thorough understanding.

2. RELATED WORK AND RESEARCH METHODOLOGY

2.1. RELATED WORK

The method of conversation (method of dialogue) refers to the adjustment of a teacher to students' abilities, based on their age and faculties. For different age groups, and also different levels of students' pre-knowledge, different approaches to formulation of questions, setting problems, discussions, etc. are employed. This method ensures better activation of students in the classroom and centers around promoting practical aspects of the work in the classroom, which is its advantage over the monologue method. Besides, by applying the dialogue method in informatics classes, students are required to make correlations between terms, draw conclusions, make generalizations thus practising independent thinking and working activities (Alexander 2008). Knowledge acquired in this manner is better understood, comprehended and remembered (Lim 2001).

The method of working with text in teaching informatics is as old as classes themselves. German didactician Paul Ficker emphasized that old schools were perceived as “bookish”, which they really were. However, great importance of written (printed) word for knowledge and teaching work should not be overlooked. This is why he uses different printed resources, such as textbooks and reference books, monographs, treatises, articles, encyclopedias, thesauruses, dictionaries, computer magazines, etc. Employing the text-based teaching method in a classroom, combined with other teaching methods, can lead to promoting intensive cognitive and emotional activities, as well as to developing of the culture of effective reading and using different literature to that end, reading with highlighting of important content, thoughts, figures, outlining headlines, reduction to ground values of what has been read, comparing text with what has been read previously (Halliday 1989). This method is highly desirable in teaching informatics, especially when working with text on computer, where students’ pre-knowledge can vary significantly (Hathorn, Rawson 2012).

The illustrative-demonstrative teaching method (showing, proving, explaining) refers to the presentation of everything that can be perceived. It is for this reason that this method is most closely related to material-technical side of teaching, with the implementation of teaching aids and labwork. In that respect, the demonstration of static objects (pictures, drawings, schematics, objects) or the demonstration of activities (dynamic structure of particular work, working processes, demonstration of working on computer, etc.) are the most frequently used. Teaching through demonstrations in informatics classroom is highly desirable because of multiple opportunities given to students to grasp and adopt principles and causalities of working in particular programming environment (Tolley, Johnson, Koszalka 2012). Cybernetic teaching methods in teaching informatics hold important place within the teaching process. Practical realization of informatics curriculum is executed on operational control level, where the teacher (control system) is the organizer and the creator of the teaching process. For mastering tasks of teaching, one needs to know about methods that lead to realization of the teaching goals, i.e. one needs to quantify students pre-knowledge in order to choose adequate teaching methods (Liu, Yang 2012).

Teaching methods for distance learning are more commonly applied in the teaching process. Electronic learning can be comprehended as the process of knowledge and skills transfer over the network through usage of computer applications and environments in process of learning (Benjamin, Krathwohl 1956).

These applications and processes include learning through the Web, the computer, in digital classrooms, and also via digital collaboration with other participants in lectures. The content can be transferred over the Internet, the intranet, as well as via video conferencing systems by video or audio tapes, by satellite TV and CD (Kilov et al. 2013). Practical application of distance learning method requires that all students have some pre-knowledge in working with software tools or that the teacher allocates time for necessary training for acquiring adequate skills (Moreira 2000), so as to ensure that this method is more effective (Ponce, López, Mayer 2012).

Defining teaching specificities in the teaching process and presenting the learning content is of utmost importance for the initial stages of the teaching process. This process can be based on the selection of a single teaching method, however a combination of several different methods applied on a planned schedule has proved more effective. Using different combinations of teaching methods results in the development of different teaching methods which to a greater or lesser degree can be applied in the teaching process with a particular objective in mind. In this line, it is necessary for the teacher to perceive all factors that affect the successfulness of the teaching methods and to evaluate best process.

In this paper, the correlation between the successfulness of the teaching methods and amount of knowledge acquired by students is considered. One teaching process is deemed more successful than the other if the students' knowledge is improved after the implementation of a particular teaching process (Žižović et al. 2013). As the teaching method is determined at the very beginning of the teaching process, a need emerges for the assessment of its successfulness in advance. As the implementation of quality teaching process largely depends on students' pre-knowledge, this paper presents a model for the estimation of the effectiveness of the teaching method based on measuring students' level of background knowledge.

The research performed so far in some of the ICS1 and ICS2 areas and published analysis (Micić, Micić, Blagojević 2013) partly facilitate a comparative view of the innovation results to the teaching process and new products on the standardization platform. The methodology enables the investigation and comparison of the results within the IT area (ICS1 = 35) in this paper.

2.2. RESEARCH METHODOLOGY

Methodologies applied in this research include statistical surveys, web browsing, the deductive-inductive inference methods for improving the process of adaptive learning, as well as numerous other methods such as analysis and synthesis, abstraction and concretization, generalization and specialization, classification and description, sampling methods, modeling, etc. (Demić 2011), as well as designing curriculum content which serves as a factor of education quality (Kopas Vukašinović, Savić 2020).

The acquisition of practical knowledge and skills needed for the inclusion in the world of work is one of the major objectives of economic development, which implies meeting the requirements of the standard or standardization platform (international ISO/IEC (ISO/IEC 2017), and national SRPS (Institute for Standardization of Serbia 2017), with examples of the knowledge sources (Micić, Tasić, Debeljković 2017), as well as the corresponding intensities of innovation (Micić, Ružičić, Tasić 2017). The intensity of innovation, the knowledge sources as cited in (Micić, Tasić, Debeljković 2017), are the basic elements of the strategy of knowledge architecture (AZ), towards economic development. The realm of IT has seen the highest innovation intensity compared to all the standardized areas of work and creativity over the past two decades.

The methodology of clustering of all standardized areas of creativity (according to ICS) was applied for the ultimate goals of AZ: daily, weekly and monthly access to sources of knowledge (at all levels of education), and for appropriate learning outcomes and inclusion in the (standardized) world of work (Micić, Ružičić, Tasić 2017; Micić, Ružičić, Blagojević 2017), by defining qualitative and quantitative indicators of innovation.

Given the facts stated above, research questions (hypotheses) defined for this study are (H0) as follows: Is it possible to predict successfulness for the chosen teaching process prior to the teaching process, based on students pre-knowledge?

The initial hypotheses have been summarized, identified and quantified in PDCA (Plan – Do – Check – Act) concept (PSU 2004) through the following questions:

H1 *Plan* phase (P) – Is it possible to plan the appropriate way of implementing the teaching process?

H2 *Do* phase (D) Is it possible to measure the knowledge of students in the teaching process?

H3 *Check* phase (C) – Is it possible to evaluate the success of the teaching process?

H4 *Act* phase (A) – It is possible to define correlations between knowledge with the intensity of innovation (Ii) and daily knowledge innovation, with checks of clustered ICS areas according to the annual intensity of innovation on the platform of SRPS and ISO standardization, with the goal of improving the teaching process?

3. RESULTS AND DISSCUSION

Results and discussion of the research are presented and discussed in accordance with the defined process through the evaluation of the effectiveness of the teaching process. The development of a methodology for the realization of the teaching process is given in Section 3. Section 3.1 presents the method of evaluation and classification of students' knowledge for purposes. Section 3.2 gives a detailed description of a method that can be used for the evaluation of the level of students post-knowledge depending on the measured level of their pre-knowledge. Based on these parameters, an algorithm for computing expected successfulness of the teaching process has been given. Additionally, a way to rank different teaching processes by the anticipated overall successfulness has been presented here. Section 3.3 providess the concept of knowledge architecture for the successful implementation of IT on the teaching process, on the platform of standardized sources of IT knowledge. The results of the continuous innovation and the determination of innovation in the teaching process is shown in the example of the IT areas.

3.1. MEASURING KNOWLEDGE IN THE TEACHING PROCESS

For the given teaching process, students' pre-knowledge of subject matter is estimated, on the value scale from 1 to n, where $n \in N$ (let S be a set of N students). For every $i \in \{1,2,\ldots,n\}$ x_i denotes students previous knowledge of subject matter at the i-th level. If $N(i)$ denotes a number of students from set S with pre-knowledge at the i-th level, i.e. if $N(i)$ denotes a number of elements from set S which are in state x_i, then the number $p_i \in [0,1]$ to each state x_i as follows

$$p_i = \frac{N(i)}{N} \tag{1}$$

The following holds

$$\sum_{i=1}^{n} p_i = 1 \tag{2}$$

When $p_i = 0$, means that there are no students with pre-knowledge of the i-th level, and $p_i = 1$ means that all the students are at the same i-th level of pre-knowledge. In particular cases, the assessment of students pre-knowledge as a prerequisite for successful application of particular teaching process can be carried out through a number of different methods (e.g. tests, prerequisite knowledge exams, design projects, etc.). In this manner, for the observed teaching process and grading scale from 1 to n, it is possible to determine degree p_i up to which group of students S fulfills i-th level of pre-knowledge, These values p_i can be viewed as probability that students of the observed group S ave acquired pre-knowledge x_i, which induces the input system

$$X : \begin{pmatrix} x_1 & x_2 & \cdots & x_n \\ p_1 & p_2 & \cdots & p_n \end{pmatrix} \tag{3}$$

which is the starting premise for further work, i.e. for carrying out a particular teaching process.

Similarly, post-knowledge, i.e. knowledge adopted and acquired by students, can be evaluated and graded after the completion of the teaching process. The criteria and their importance in evaluating pre-knowledge and post-knowledge do not necessarily need to be identical, inasmuch as the scales used for the assessment also do not need to be identical. Here, it is assumed that assessing students' post-knowledge ranges from 1 to m on the value scale. For example, in some cases students' previous knowledge of subject matter can be estimated in this manner: 1 – bad, 2 – good and 3 – excellent, while their post-knowledge at final exam can be evaluated from 1 to 100 points.

For any $j \in \{1,2,\ldots,n\}$, let y_j be post-knowledge at the level j and let $M(j)$ be a number of students who acquired knowledge at the level j after completion of teaching process. Value $q_j \in [0,1]$ given by equation

$$q_j = \frac{M(j)}{N} \tag{4}$$

represents the degree up to which the group of students S adopted and acquired knowledge at the j-th level. The following holds true

$$\sum_{j=1}^{m} q_j = 1 \tag{5}$$

Is obtained system which is called the output system or the consequence of the teaching process. For every $i = 1,2,\ldots,n$ and $j = 1,2,\ldots,m$, let $R(i,j)$ be a number of students who start with pre-knowledge x_i, at the end of teaching process possess post-knowledge y_j, i.e. let $R(i,j)$ be a number of transitions from input state x_i into output state y_j. To each pair of states x_i and y_j a number $r_{ij} \in [0,1]$ can be associated. Let $w_{ij} \in [0,1]$ represent the degree of satisfaction with the transition from input state x_i into output state y_j, i. e. w_{ij} represents the degree of satisfaction with obtained results of students who start from the i-th level of pre-knowledge adopted the post-knowledge at the j-th level. For example, students with high pre-knowledge can be expected to achieve greater post-knowledge, thus the corresponding degree of satisfaction is low, but if a student with low level of pre-knowledge reaches higher level of post-knowledge, than this degree of satisfaction is huge.

Hypotesis 0 is analyzed as follows: Is it possible to predict successfulness of the chosen teaching process at the beginning of teaching process, depending on students' pre-knowledge?

Specifically, if we need to choose from a number of teaching methods the one that can be defined as the most effective for determining students' previous knowledge, the method to be shown in the section that follows may best satisfy the criteria.

3.2. EVALUATION OF THE SUCCESS OF TEACHING PROCESS

In the given finite probabilistic system

$$X:\begin{pmatrix} x_1 & x_2 & \dots & x_n \\ p(x_1) & p(x_2) & \dots & p(x_n) \end{pmatrix} \tag{6}$$

$x_1, x_2, \dots, x_n$ are of states and $p(x_1), p(x_2), \dots, p(x_n)$ are the corresponding probabilities. This system is called the input system and its states interpret students pre-knowledge.

Let there be given states $y_1, y_2, \dots, y_m$ of the output system

$$Y:\begin{pmatrix} y_1 & y_2 & \cdots & y_m \\ p(y_1) & p(y_2) & \cdots & p(y_m) \end{pmatrix} \tag{7}$$

whose probabilities $p(y_1), p(y_2), \dots, p(y_m)$ are to be determined.

For each $i \in \{1,2,\dots,n\}$ and each $j \in \{1,2,\dots,m\}$ let $p(y_j \mid x_i)$ denote probability that post-knowledge y_j can be achieved starting with pre-knowledge x_i, i.e. $p(y_j \mid x_i)$ denotes probability that will becomes y_j at the exit side, for x_i on the entrance side. Is called transformation matrix of the input system X into output system Y. Following equality it holds that

$$\sum_{i=1}^{n} p(y_j \mid x_i) = 1 \tag{8}$$

The evaluation of the effectiveness of a particular teaching process is given by $U(K)$. In the case of a number of different treatments of the teaching process

$$K_1, K_2, \dots, K_n \tag{9}$$

which can be applied on the same input system X, then the corresponding transformation matrices $T_1, T_2, \dots, T_k$ need to be defined. Note that these matrices can be obtained statistically by monitoring a teaching process over a longer time period, i.e. by experience of a teacher. Matrices $T_1, T_2, \dots, T_k$ induce corresponding (hypothetical) output systems

$$Y_1, Y_2, \dots, Y_k \tag{10}$$

upon which the successfulness of the teaching process can be estimated. In this manner, the obtained values are as follows:

$$U(K_1), U(K_2), \dots, U(K_k) \tag{11}$$

If the K_p teaching process is said to be better than the K_q, teaching process according to (Žižović et al. 2013), then it is valid that:

$$K_p \geq K_q \tag{12}$$

if this inequality holds true

$$U(K_p) \geq U(K_q) \tag{13}$$

3.3. THE CONCEPT OF KNOWLEDGE ARCHITECTURE FOR THE SUCCESSFUL IMPLEMENTATION OF IT ON THE TEACHING PROCESS

The knowledge architecture (AZ) concept is based on the concept of a source of knowledge according to ICS (the standardization platform). The concept is directly related to higher education through the clustering of the area of creativity (according to ICS levels). ICS areas are grouped by areas of higher education – with the corresponding intensities of innovation (Ii – as the sum of the index of development projects, $Iqu/_{ISO}$ and the index of publications $Iqp/_{SRPS}$):

1. clusters (according to II) of innovation: daily, weekly, monthly and yearly,
2. ranking of all ICS areas, on the examples of IT and other sectors of economic development (by Ii).

The methodology enables the investigation and comparison of the results in IT area (ICS1 = 35, according to (Micić, Micić, Blagojević 2013). Studies performed so far and the published analysis in certain ICS1 and ICS2 areas, partly facilitate a comparative view of the innovation results to the KBS for ES and new products on the standardization platform, for DSS and managing innovation.

IT innovations are the best example for modeling AZ on the ICS platform and in all standardized areas of creativity, for $U(K_p) \geq U(K_q)$ criteria (13). If growing index of development projects (Iqp), growing and innovation index (Ii).

The concept of AZ on the platform of standardized sources of knowledge (Micić, Ružičić, Tasić 2018) and (especially) by ICS-areas of daily innovation is the basic lever of development of methodology for successful realization of both the teaching process K_p and the concept of AZ.

The methodological approach in correlation with the research on the standardization platform includes determining the growth of knowledge sources (ΔKS) and the innovation index (Ii/t) in ICS areas, for updating knowledge base (KB) and knowledge base system (KBS). In the general case, for the total statistical sample (Iqs) or the source of knowledge (KS) the relation/equation is valid, according to:

$$\text{Iqs (KS)} = \text{Iqp} + \text{Iqw} + \text{Iqu} + \text{Iqd} \tag{14}$$

Volume indices by categories of KS are as follows: Iqp – number of current published sources of knowledge, Iqw – number of withdrawn sources of knowledge, Iqu – number of projects in various stages of development, Iqd – number of deleted documents (in the last 12 months).

If $1 \leq \Delta KS_{DK/t} < 12$, innovation is annually, $12 \leq \Delta KS_{DK/t} < 50$ – monthly, $50 \leq \Delta KS_{DK/t} < 250$ – weekly and $250 < \Delta KS_{DK/t}$ – daily.

The methodological approach involves the application of criteria (14) for clustering innovation and determining the innovation index ($Ii_{/t}$):

$$Ii_{/t} = 4, \text{ за } 250 < \Delta KS_{DK/t} \leq 500 \ (t = \textit{daily intensity } \Delta KB/ \textit{ daily}) \quad (15)$$

The concept of knowledge architecture for the successful implementation of the IT teaching process is shown in the example of the IT areas, through the results of continuous innovation and the determination of innovation in teaching process:

1. Continuity of monitoring the intensity of knowledge innovation, in order to improve the teaching processes while anticipating and providing resources and knowledge for the development of systems and products using modern IT (with the highest intensity of innovation), planning of resources, activities and tasks for daily product innovation in ICS areas based on original trend lines, starting from the source of knowledge (Figure 1).

2. Determination of comparative index indicators (quantity and value index) for relevant areas, in domain of ICS areas, to monitor trends in knowledge innovation, to improve teaching process quality.

3. Determination of the innovation intensity index represents a prerequisite for clustering, appropriate frequency of checking (base, trend) in ICS areas (Ružičić, Micić 2017) and Measuring knowledge in teaching process knowledge and performance for IT users (daily innovation cluster – one innovation per day), according criteria (15).

4. If several different teaching methods in some teaching process in IT are applicable (ICS1 = 35), then successfulness of each of those methods before the beginning of teaching process can be evaluated. In this manner, one can choose the best and the most successful process, the one that can give the best results at the end of the teaching process, with respect to the students' knowledge.

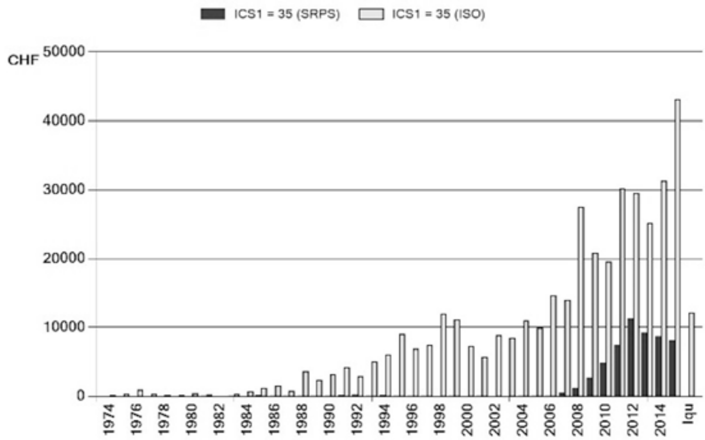
4. CONCLUSION

According to the results presented in Section 3 the basic hypothesis has been proven, i.e. it is possible to predict successfulness of a chosen teaching process at the beginning of teaching process, depending on students pre-knowledge.

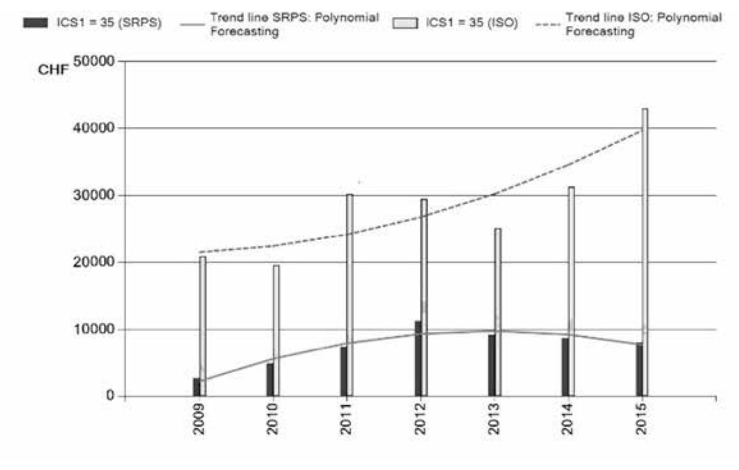
Based on the presented hypothesis and results, what follows are the conclusions reached through the PDCA methodology:

Figure 1. Sources of knowledge for ICS1 = 35 (Information Technology) (1.2016):
a) summary results of the analysis, b) trend lines for the period 2009–2015

a)



b)



1. (P) – It is possible to plan an appropriate way of implementing the teaching process (Section 3.1);

2. (D) – It is possible to measure the knowledge of students in the teaching process. The evaluation of knowledge sources enable getting explicit mathematical relations, and also trend lines of knowledge, as well as the possibility of comparing all the areas with creativity (Section 3.1);

3. (C) – It is possible to evaluate the success of the teaching process (Section 3.2);

4. (A) – There is a possibility of defining correlations between knowledge with the intensity of innovation (Ii), with checks of clustered ICS areas according to the annual intensity of innovation on the platform of SRPS and ISO standardization as well as between daily knowledge innovation, with the goal of improving teaching process (Section 3.3).

In some teaching processes, several different teaching methods can be applied. Also, it is also possible to perform an assessment of successfulness of each of the methods applied prior to teaching. In this manner, a single process yielding good (or by applying this methodology the best) results at the end of teaching process can be determined, viewed from aspect of knowledge acquired by students.

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РАЗВОЈ МЕТОДОЛОГИЈЕ ЗА УСПЕШНУ РЕАЛИЗАЦИЈУ НАСТАВНОГ ПРОЦЕСА

Резиме: Овај рад представља један развој методологије за успешну реализацију наставног процеса и пример примене у ICS области информационих технологија (ИТ), ICS1 = 35. ICS областима додељују се мерљиви квантитативни показатељи иновативности. Студија представља резултате истраживања интензитета иновативности знања који су изузетно значајни за побољшање квалитета наставног процеса на ISO и SRPS платформи. На самом почетку сваког наставног процеса постоји потреба за одабиром одговарајућих метода извођења наставе, на такав начин да буде у складу са циљевима и задацима тог наставног процеса. Истовремено, тај наставни процес може се максимално прилагодити, а задржати, колико је то могуће, у складу са бројним унутрашњим и спољашњим факторима као што су: основно предзнање ученика, њихова мотивација, њихове опште и специфичне способности (простор, библиотека и остали ресурси), као и примена ИТ. Резултати континуираних иновација и одређивање иновација у наставном процесу фокусирани су на примерима области ИТ. У овом раду дат је један модел за процену успешности наставних метода заснован на мерењу претходног знања студената. Ако се у наставном процесу може применити неколико различитих метода реализације наставе, тада постоји могућност да се изврши процена учинка за сваку од ових метода, пре него што наставни процес започне. На тај начин се утврђује једна методологија која може донети добре резултате на крају наставног процеса, гледано са аспекта знања које су студенти стекли.

Кључне речи: развој, методе, знање, мерење, оцењивање, наставни процес, ICS, ИТ.