Building of the dynamic models of visualization of the methodology for assessment of the level of students' competencies creation

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Abstract. One of the important task of the education system is to ensure the high quality training of students with a competency-based approach. The authors offered a scenario of the visual assessment technique of the level of students’ competencies creation with the usage of software tools, which together with innovative diagnostic algorithm allow to provide the analysis of educational data, see the results of the educational program learning and draw the conclusion about the level of students’ created competencies. The software tools are based on the ranking of components “knowledge – efficiencies – skills”, that is used for solving the problem of assessment of the levels of students’ competencies creation by the method of hierarchical system of fuzzy inference and centre-of-influence method. Statistical processing of the educational outcome is built in the developed program scenario that allow to provide a comprehensive visual presentation on analyzed sample of input data. Data display using the proposed data and obtained graphs allows to define vulnerabilities of the training of the students and the capacity to deal with them. On the use of developed scenario it is possible to observe the dynamics of students’ competencies creation and to improve the methodology and technology of educational process.

1. Introduction

One of the important tasks of the education system is to ensure the high quality training of university graduates with a competency-based approach. A number of scientific studies have proposed the different methodologies and software tools for assessment of the students’ competencies creation.

In the article [1] shows the results of the creation of competency based experiment programs and contents that are aimed at filling gaps in skills and/or knowledge. According to the authors, such a program will give clear, sound and protected assessments, and the methods will form final results of measuring of the success of students and efficiency of learning process on the whole. The authors [2] describe innovative methodology that combines competency model and theory of education needs analysis for creation of efficient self-assessment tool. The tool is for analyzing the needs of competencies development on the basis of input data required for qualitative assessment of basic skills of students and monitoring of their personal development progress. In the article [3] presents impact analysis of efficiencies formed during the learning process and skills demanded by labour market to solve professional tasks. In the article [4] examines the model and the method of students’ competencies assessment in the system of e-learning, testing of purposes fulfilment of educational program and creation of student’s competence model formed as purpose when entering. The authors suggest assessment on the level of discipline, module and testing of purposes achievement of educational
program. The research [5] aimed at identification of common skills that should be formed in the process of learning activity by using dual assessment approach – survey of the students and using data collection tools and its analysis. The purposed mechanism allows to assess the results of the competencies identification according to students. In the article [6] assessed students’ competencies formation tools on the basis of data mining. The authors think that computer-based tools give more trustworthy results as compared to feedback procedures and they are available and versatile. In addition, using data on learning processes and its results, computer tools can be used for cognitive diagnostics and educational analytics: to conduct an in-depth assessment of the levels of students’ competencies and automatically submit subjects and tests based on comparative empirical data. The authors believe that such technologies will facilitate the creation of a customized learning environment.

Research analysis showed that in the combination with innovative diagnostic algorithms it is possible to implement powerful mechanism aimed at assessment of the model of students’ created competencies. The key requirements to the students are not only the formation of theoretical knowledge and practical skills but also the ability to apply them for solution of the professional problems, to generate new ideas and approaches, and also to determine the ways of its implementation [7]. Therefore, a new paradigm is required to assess the quality of competency-based programs. It is important to understand that the large amount of data is formed in the educational process, that changes dynamically over time, allow monitoring the results aimed at the level of created competencies for understanding the problem-solving skills of graduates and at the adjustment of educational process. Real-time visualization of the dynamic result assessment of the educational process allows students and teachers to adjust their approach to the learning process.

The purpose of the study is to build dynamic models of visualization of the methodology for assessment of the level of students' created competencies through software tools implementation and its further use. This tool will be focused on solving the problem of centralization of big data to obtain new knowledge structures that support the dynamic acceptance of students’ needs [8]. At the same time, the effectiveness of students’ assessment will depend directly on the effectiveness of designing the framework of proposed software tool [9]. The product should create dynamic graphs resulting the process of assessment of the level of students’ created competencies based on the method and structure that help to make the knowledge base measurable or, more accurately, “quantifiable” [10].

2. Materials and research methods

According to existing approaches, competency (y) can be defined by three main group indicators: “knowledge” (Z1), “skills” (U1) and “practice” (V1). Each of these indicators depends on many others, for which it is difficult to obtain clear quantitative estimations. The solution to the problem of assessing the created competence is possible on the basis of a hierarchical system of fuzzy inference [11]. In such systems, the output of one knowledge base is fed to the input of another, higher level of hierarchy. Competence is formed in the process of studying a certain number of disciplines (Dn). Moreover, each of them contributes to the overall indicator with a certain weight of credit units (ω(Z)). In a first approximation, this contribution can be estimated by the ratio of a given number of credits for studying the discipline to the total number of credits that form a specific competency. Consequently, the assessment of the creation of competence can be reduced to the construction of the model, which is shown in figure. 1.
In the framework of educational activities, competency can be formed at one of the levels: threshold, basic or core. To determine the assessment of the level of achievement of competence, the center of gravity method was chosen, which allows the most efficient way to represent the process of finding a clear value of \( y \) for a given fuzzy set of input credit units \( ZE \) [12]. This method is recognized as more simple and provides a higher sensitivity of the fuzzy model to changes in input data.

The center of gravity (centroid) is calculated by the formula:

\[
Y_g = \frac{\int_{\min}^{\max} y \cdot \mu(y) dy}{\int_{\min}^{\max} \mu(y) dy}
\]

where \( Y_g \) – result of acquired competency level; \( y \) – a variable corresponding to the output parameter (level of achievement of competence); \( \mu(y) \) – membership function corresponding to the output variable; \( \min, \max \) – the left and right points of the range of the carrier of the fuzzy set of the considered output variable.

The process of assessing students' competencies requires a large number of operations related to determining the levels of learning of theoretical knowledge and practical skills, the ability to apply them in applied fields, and calculating the indicators of created competencies [13]. In fact it is necessary to undertake the process of gathering, analyzing and interpreting information about the success level of students, i.e. the issue raises of an automatic learning analytics system with great opportunities to support the education and visualize obtained data. Visual representation of the results will allow teachers and students monitoring the dynamic patterns of changes of the level of students' competencies by examining the results and drawing conclusions. Therefore, it is necessary to make appropriate visualized support of the educational process that is aimed at controlling of acquirement of knowledge, abilities, and skills based on competencies formation. This support can be provided through the implementation and subsequent use of the software tools in the educational process containing information for students about the performance results and for teachers about the dynamics of changes of academic progress obtained by both an individual student and a group. Such visualization must be carefully designed for unimpeded communication between students, teachers and analytic system in order to provide effective pedagogical interaction.

3. Results and discussion

For assessment of students' created competencies a number of researchers proposed their own methods of using information technologies and instrumental environments. The authors [14] believe that the development of the new technologies requires a new set of practical skills and skills in digital tools.
support. They compare learning outcomes with taxonomies in order to proceed from assessment based on requirements to competency based assessment. The created model can be used for development of educational programs for general competencies and skills development that are necessary for professional activities. The project [15] showed the relevance of mobile technologies for evaluating the learning process and the level of competencies formation. In the article [16] provides assessment of stealth integrated in gaming technologies for assessment of students’ problem-solving skills. The authors showed that problem solving assessment obtained from the game are comparable with the level of required skills formation. The managerial competence assessment instrument [17] was validated using evaluation data from the given data sampling. In the article [18] presents the use of autonomatical video recording service for integration and assessment of general competencies. The implemented service allows to conduct the assessment through the methodologies of active and group learning using information and communication technology as support, becoming a learning resource where students have to assess their own activities and general competencies.

Research analysis showed that assessment of the level of competencies requires different software tools but they do not allow to visualize the results. In the framework of this study, to solve the problem of assessing the achieved level of competencies, a prototype of software tools developed by using the programming language R [19] was proposed. To implement the required reflection functions in visual form of the results obtained in software tools, the lattice package was used, which is a powerful and stylish high-level data visualization system with an emphasis on multidimensional data and aimed at developing Trellis graphics.

The implementation of software tools was based on an algorithm that includes the following steps:

1. Preparation and loading of source data. The source data used was a file born in an Excel spreadsheet and containing information on the results of an expert assessment of the creation of students' competence. Assessment of the creation of knowledge, skills and practice was carried out by experts among students of 10 tested study groups in 11 disciplines of the current curriculum involved in the creation of students' competencies.

2. The calculation of the average score for students of the tested groups within the framework of the created competencies for the elements “know”, “be able”, “own” is performed in the following teams:

```r
students.cnt <- length(unique(df_competence[,”student”]))
num <- df_competence[1:students.cnt,”num”]
students <- aggregate(cbind(know, can, apply, mean) ~ group + student, data = df_competence, mean)

group <- students$group[students$student==student]

rownames(group.students) <- 1:nrow(group.students)
```

3. Analysis and printing of results. The calculation results are formed in the form of graphs, which allows you to visually evaluate the creation of students' competencies.

The results of the creation of knowledge, skills and practice of students in the framework of assessing the level of competencies for 10 test groups are shown in figure 2. The graphs display in a visual form the level of creation of students' competencies.

The graphs show that the average level of knowledge of all students in group 01 is mainly within 4 points, i.e. in this group, the creation of competencies on the element of “knowledge” at one level. In groups 04 and 07, the average level of knowledge creation varies from 2 to 5 points, which indicates a different level of learning of theoretical material within the group.

In general, the obtained graphs make it possible to identify both the weakest and the most powerful groups of students in mastering competencies. Thus, by analyzing academic performance charts, it can be determined that of the 10 tested groups, the most “strong” group is group 10. The main contingent of students of the selected group has an average score of 4 or 5 for all elements “know”, “be able”, “own”,

```r
```
which speaks of a high level of competency creation and shows the mastery of the curriculum disciplines at a fairly high level. A similar conclusion can be drawn on the 02 group.

![Figure 2. The average result of the creation of knowledge (a), skills (b) and experience (c) for 10 test groups.](image)

At the same time, it is clear that in group 01 the level of competency creation is stably average. The average score for all elements of “know”, “be able”, “possess” within the group is 4 points. In the remaining groups, the results vary from 3 to 5 points, in some cases 2 points were discovered.

After analyzing the totality of all tested groups, you can determine the level of creation of the competencies of a particular student. As a result of the following fragment of the program script, in the global environment \( R \), a \( \text{df\_student} \) data frame is created containing information about the given student.

```r
df.student<- df_competence[df_competence$student == student,c(1:3, 5:9)]
group <- as.character(df.student$group[1])
num <- df.student$num[1]
caption <- paste(group,": ", num, ". ", student, sep = "")
cat("\n\n", caption, "\n\n", sep="")
cat("----------------------")
df.student<- df.student[,c("discipline", "competence", "know", "can", "apply", "mean")]
```
In figure 3 presents for a randomly selected student the total scores of the elements “know”, “be able” and “own” in all disciplines involved in the creation of competencies.

![Image 1](https://via.placeholder.com/150)

**Figure 3.** The total score of knowledge (a), skills (b) and practice (c) in all disciplines for Student_187.
Figure 4 shows the dependence of the average score on quantiles. The division of the graph by vertical lines into three areas allows to visualize the relation to one of the three clusters in terms of performance. Cluster division might be defined to “low”, “medium” and “high” levels. The black dots on the graph show the average scores for each student in the group, the results by the elements “know”, “be able”, “own” are highlighted in appropriate colors. Such visualization allows to clearly determine the grades of the student for all subjects and the relation to one of three clusters in terms of performance.

In addition, the statistical processing of the educational results was added to the developed software product. For example, with the use of the `summary()` function the following results were obtained: the minimum and maximum values, median center, arithmetic mean, values of the first and third quartiles, and therefore a more complete view of the analyzed sample was obtained. Additionally, the average value for each column for the group, standard deviation and confidential interval were obtained through the corresponding statistical functions. Figure 5 shows the results of the descriptive statistics of the data selection by the elements “know”, “be able”, “own” and “average value” on the example of the study group for the selected competence within the subject.

![Figure 4. Visual representation of the results.](image)

**Figure 5.** Descriptive statistics for the competence within the subject for the study group.

| Average rating: 3.97 |
|---------------------|
| Standard deviation: 0.64 |
| 95%-Confidence interval: [2.7, 5.24] |
| **Summary statistics:** |
| **know** | **can** | **apply** | **num** |
| Min.: 2.000 | Min.: 3.000 | Min.: 2.000 | Min.: 1.00 |
| 1st Qu.: 4.000 | 1st Qu.: 3.000 | 1st Qu.: 4.000 | 1st Qu.: 6.75 |
| Median: 4.000 | Median: 4.000 | Median: 4.000 | Median: 12.50 |
| Mean: 3.875 | Mean: 3.958 | Mean: 4.083 | Mean: 12.50 |
| 3rd Qu.: 4.000 | 3rd Qu.: 4.250 | 3rd Qu.: 5.000 | 3rd Qu.: 18.25 |
| Max.: 5.000 | Max.: 5.000 | Max.: 5.000 | Max.: 24.00 |

Figure 6 shows the silhouette diagram with all of the data that is divided into three clusters through the PAM clustering algorithm. Silhouette analysis allows to figure how similar the observations in the cluster are to each other in relation to other clusters. The silhouette diagram shows the spatial relation to one of the three clusters according to the average results of each student in the sample of input data, how close each point in one cluster is to the points in neighboring clusters, and therefore allows to visually evaluate such parameters as the number of clusters.

Division of the students into groups was carried out through the developed assessment technique of the level of created competencies that was based on implemented software tools. Figure 7 shows the result of a grouping of assessed students according to the level of competency creation according to the proposed visualization technique, which showed high results of students' readiness to solve professional problems and the performance of the proposed tools.
Consequently, with the developed tools, it is possible to analyze the performance results of any student of a given sample. To process a new selection, you should include at the beginning of the program script a .csv file prepared for processing or a MySQL database.
Consequently, with the developed tools, it is possible to analyze the performance results of any student of a given sample. To process a new selection, you should include at the beginning of the program script a .csv file prepared for processing or a MySQL database.

Thus, the proposed software tool will be useful for students and teachers as it translates educational data into graphical form suitable for both informative and summative assessment. This avoids the errors in interpretation of the data that break down the competencies into sections by compiling the several behaviors for each competence into a single visual tool or “radio-locating graph” (figure 8) [20]. This tool will help students to understand their educational results and teachers to draw conclusions on the adjustment of the educational process.

Data mapping using the proposed tool and obtained graph allows to identify weaknesses in schooling of students and to find opportunities for their elimination. On the basis of the graph it is possible to observe the dynamic of the building of students’ competencies and to adjust the methodology and technology of the educational process.

The proposed methodology for assessing the level of students' created competencies using software tools and visual graphs can be used for processing the big educational data. Presentation of the analysis results in the form of the diagrams and graphs gives the opportunity to analyze the information in real time that helps to adjust the learning process in good time. The assessment of the level of students' created competencies is conductive to further planning of the learning process in a specific discipline.

4. Conclusion
This study presents a prototype of software tools in the programming language $R$, which allows demonstrating in a visual form the dynamics of mastering the disciplines of the curriculum and the educational results obtained by both an individual student and a group. This allows you to see the results...
of mastering the educational program by students and draw a conclusion about the level of formation of the competencies of graduates.

In addition, the application of the method of conducting the radio-locating graph contributes to the demonstration of proposed results of students' created competencies based on the ranking of elements “know – be able – possess” that allows to conduct a more comprehensive analysis of educational data to identify the weaknesses of the educational program and to improve the learning process by adjusting its organization and planning.

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