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IMPROVING A GENERALIZED APPROACH TO ASSESSING THE LEVEL OF COMPETENCE DEVELOPMENT OF SCIENTIFIC AND PEDAGOGICAL STAFF AT HIGHER MILITARY EDUCATIONAL INSTITUTIONS

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This work assesses the level of competencies development by the scientific and pedagogical workers at higher military educational institutions.

The task addressed is the need to increase objectivity and accuracy in assessing the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions.

Within the framework of this study, a generalized approach to assessing the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions includes a methodology and an assessment procedure.

The methodology for assessing the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions has been improved by applying the principal component method to it.

That has made it possible, in contrast to conventional methodologies based on simple averaging of assessment results, to eliminate multicollinearity, ensure maximum objectivity and accuracy in assessing the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions.

It is proven that ignoring internal correlations leads to the loss of important information and a biased assessment of the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions.

The procedure for assessing the level of development of the competencies of scientific and pedagogical workers at higher military educational institutions has been improved, which is based on an improved methodology, which made it possible to increase the objectivity and accuracy of the assessment by 16.6%.

It has been confirmed that taking into account the sources of origin of the competencies of scientific and pedagogical workers at higher military educational institutions is an important component for their objective and accurate assessment.

The practical significance of the improved approach to assessing the level of development of competencies in the activities of personnel services at higher military educational institutions has been determined

Keywords: assessment of competencies, sources of origin of competencies, scientific and pedagogical workers, principal component method

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1. Introduction

Objectivity and accuracy in assessing the level of competence development are fundamental conditions for making informed management decisions regarding the selection and appointment of candidates for positions of scientific and pedagogical workers (hereinafter referred to as SPWs) at higher military educational institutions (hereinafter referred to as HMEIs).

As noted in study [1], one of the main problems in modern higher education is staff turnover. After all, staff turnover affects the management of human resources, personnel policy, economic security of the higher education system, the budget for higher education, and most importantly, the quality of such education.

In the context of the transformation of the security and defense sector, this problem becomes critical as the training of highly qualified specialists capable of performing tasks under combat conditions directly correlates with the professional level of the teaching staff.

However, an analysis of existing practices for assessing the level of competence development reveals the existence of a methodological dichotomy [2–8].

Thus, traditional approaches are either characterized by excessive simplification of the object of assessment or are marked by excessive cumbersomeness due to an unjustified increase in the number of indicators [2–5].

Simplified models, as a rule, ignore the origin of competencies, not taking into account such sources of their origin as general development and previous experience, limiting themselves to only a narrow list of professional knowledge, skills, and abilities.

On the other hand, attempts to cover the widest possible set of indicators without taking into account their internal correlation are the basis for the emergence of multicollinearity of independent variables. This leads to artificial overestimation or underestimation of individual indicators, which eliminates the objectivity and accuracy of their integral assessment [6–8].

Therefore, there is an urgent need to increase objectivity and accuracy in assessing the level of competence development of HMEI SPWs.

This can be solved by improving the generalized approach to assessing the level of competence development, namely, improving the assessment methodology using the principal component method and the assessment procedure itself.

Thus, the task to improve objectivity and accuracy in assessing the level of competence development is relevant.

2. Literature review and problem statement

The author of work [2] used comparative and content analysis methods to investigate the issue of assessing the managerial competencies of managers, based on the performance indicators of the organizations they manage. That made it possible to use the benchmarking methodology, select evaluation indicators, and group them into two categories: "economic performance" and "social performance". However, in work [2], the issue of taking into account other competencies and the probabilistic connection between them remained unresolved. This issue is not resolved since the author focused exclusively on assessing the level of development of managerial competence.

At the same time, that issue was paid attention to in [3], in which the author, using a system analysis, investigated the competencies that have a direct impact on the level of training of the variable staff of the training center. That made it possible to propose a methodological approach to assessing the level of competencies, which is built on the basis of calculating a multi-criteria dimensionless assessment. The author also identified such competencies as knowledge of subjects in training programs, individual psychological and volitional qualities, motivation for work. However, in work [3], the issue of taking into account other competencies to obtain a comprehensive assessment and establish indicators for their assessment remained unresolved. This issue was not resolved since the author did not take into account the importance of a comprehensive assessment of competencies. This issue was paid attention to in [4], in which the author, using the analysis of scientific research, substantiated a comprehensive approach to personnel assessment, which is based on the provisions of the professional standard and the principles of comprehensive assessment. That made it possible to propose a structure of indicators that reflect the main areas of activity, namely professional and legal, organizational, and managerial and personal and psychological competencies, and to determine the criteria for assessing each indicator for objectivity and transparency of the assessment. However, in work [4], the issue of substantiating the tools for assessing the level of formation of the proposed competencies remained unresolved. This issue is not resolved since the author focused exclusively on the structure of indicators and the criteria for evaluating each of them.

However, the author revealed that issue in [5], in which, using a system analysis, the diagnostic tools for the level of competence development were studied, which include both quantitative methods and qualitative approaches. That made it possible to typify the main diagnostic tools relevant for assessing competences and to justify that for effective diagnostics, a holistic multidimensional approach is necessary, combining quantitative and qualitative assessment methods. However, in [5], the issue of a unified procedure for assessing competences remained unresolved. This issue was not resolved because the author did not take into account that an increase in the number of methods leads to an artificial "burdening" of the assessment process, requires the involvement of highly qualified specialists, and the expenditure of significant financial, material and time resources. The author paid attention to this issue in [6], in which, using methods of analysis, synthesis, multidimensional modeling and a comparative approach, methods for assessing the level of human intellectual potential by types of competences were investigated. That made it possible to substantiate a universal functional model of the assessment system, which includes a qualimetric factor-criteria model, an algorithm for calculating the level of competence reproduction, and a technique for quantitatively assessing the level of competence potential. However, in work [6], the issue of eliminating duplication of competence assessment results remained unresolved, which in turn can lead to artificially distorted assessment results. This issue is not resolved since the author focused exclusively on the qualimetric assessment model.

In work [7], the author investigated the problem of duplication of indicators within the subcriteria for assessing the professional and personal qualities of candidates in an assessment approach based on linear summation of correlated assessment indicators. That made it possible to propose an assessment model based on the exclusion of repeating indicators from the criteria and the corresponding adjustment of the sum of points that will be awarded for one or another integral criterion. However, the issue of formalizing the relationships between dependent variables remained unresolved in [7]. This issue is unresolved because the author did not take into account that the use of regression analysis methods provides a toolkit for formalization and makes it possible to quantitatively describe the dependences between real indicators.

At the same time, that issue was given research attention in work [8], in which the author thoroughly analyzed statistical violations, namely multicollinearity, heteroscedasticity and autocorrelation of residuals. That made it possible to establish that systematic detection and correction of these violations using the principal component method are critically important for increasing the accuracy of forecasts and reliability of conclusions. The application of the principal component method is considered by the author as a tool for minimizing the dimensionality of features while maintaining the maximum amount of necessary information. However, in work [8], the issue of ensuring maximum objectivity and accuracy of data acquisition when assessing the level of competence development, without losing the necessary information, remained unresolved. This issue is not resolved since the author paid attention exclusively to the elimination of statistical violations that arise when applying regression analysis methods.

Based on the results from our review of the literature [2–8], it was possible to systematize the identified local problems, which include the impossibility of taking into account a significant number of competencies, the probabilistic relationship between them and the establishment of indicators for their assessment. These problems also include the justification of the tools and a unified assessment procedure, eliminating duplication of results, formalizing the relationships between dependent variables, and ensuring objectivity and accuracy of data acquisition without losing the necessary information. This led to the conclusion that a general unresolved problem is the need to improve objectivity and accuracy in assessing the level of competence development.

It is possible to solve this problem by improving the generalized approach to assessing the level of competence development, including HMEI SPWs. This is what allows us to assert that it is advisable to conduct a study aimed at improving the generalized approach to assessing the level of competence development by HMEI SPWs.

3. The aim and objectives of the study

The purpose of our study is to improve the generalized approach to assessing the level of competence development by HMEI SPWs, taking into account the requirements of modernity. This will provide the opportunity to ensure maximum objectivity and accuracy in assessing the level of competence development during the assessment procedure.

To achieve the goal, the following tasks were set:

– to improve the methodology for assessing the level of competence development by HMEI SPWs;

– to improve the procedure for assessing the level of competence development by HMEI SPWs.

4. The study materials and methods

The object of our study is to assess the level of competence development by HMEI SPWs.

The hypothesis of the study assumes that the maximum objectivity and accuracy in assessing the level of competence development by HMEI SPWs is ensured by transforming a significant number of correlated indicators into several independent principal components.

The following assumptions are adopted in the study:

– the principal component method works equally well with data obtained from both a small and a large sample;

– taking into account the sources of origin of competencies allows for a comprehensive consideration of the generalized competence of HMEI SPWs;

– the competence of the person conducting the assessment allows for an accurate reflection of the essence of principal components.

The study reduced the number of respondents and the number of competencies for a simplified reflection of the procedure for assessing the level of competence development of HMEI SPWs.

Within the framework of this work, the principal component method was used as a theoretical research method.

The principal component method is one of the methods in multivariate mathematical statistics. This method is intended for estimating the parameters of models with a large number of independent variables and in the presence of multicollinear variables.

The advantage of the principal component method is that it makes it possible to reduce the dimensions of the studied data with minimal loss of useful information and is the only mathematically justified method of factor analysis [9,10].

The essence of the method is to reduce the number of factor variables to the most significantly influencing factors. This is achieved by linearly transforming all factor variables into new variables, which are defined as principal components [9].

The principal component is defined as a normalized-centered linear combination of indicators that is not correlated with previous principal components and has the largest variance among other linear combinations of variables [9].

The first principal component will correspond to the maximum of the total variance of all variables, the second component – the maximum of the variance remaining after eliminating the influence of the first component [9].

With the help of the first few principal components, almost all the variability of the data is explained, and the others reflect random errors.

The general algorithm for applying the principal component method consists of several stages.

The stage of sample formation and data collection. This stage is determined to be important for ensuring the reliability, validity, and statistical correctness of the further application of the principal component method.

Its content is determined in the formation of a representative sample, the organization of procedures for collecting qualitative and quantitative data, as well as the construction of a primary observation matrix where the collected data is formed into a structure [10]:

$$X=[x_{ij}],\quad i=1..n,\quad j=1..p, \tag{1}$$

where x_{ij} is the value of the j-th indicator for the i-th respondent, n is the number of respondents, p is the number of indicators.

The stage of statistical preparation of data and selection of the dispersion matrix. This stage is a key prerequisite for the correct application of the method of principal components. It provides for the performance of statistical tasks that ensure the mathematical suitability of data for spectral decomposition.

The first of them defines the centering of variables, which provides for the subtraction of the average value of each indicator [10]

$$x'_{ij} = x_{ij} - \bar{x}_j, \quad (2)$$

where x_{ij} is the initial value of the j-th indicator for the i-th respondent, $\bar{x}_j$ is the average value of the j-th indicator.

The next task is defined as data standardization [10]

$$Z_{ij} = z_{ij} = \frac{X_{ij} - Xj}{Sj}, \quad (3)$$

where the standard deviation of the j-th indicator

$$s_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij}\right)^2}. \quad (4)$$

The standardization process eliminated the dominance of indicators with large values, which is a prerequisite for the principal component method.

The next task was to check for multicollinearity, measure the degree of suitability of the data for factorization, and select the type of scattering matrix.

The stage of direct application of the principal component method. At this stage, the latent components were isolated. This stage includes several tasks.

The first of them was to construct a correlation or covariance matrix, which is denoted as follows [10]

$$R = \left(r_{ij}\right), \text{ or } C = \left(c_{ij}\right). \quad (5)$$

Such a matrix is defined as the basis for further spectral decomposition when the following problem is solved [10]

$$Rv_k = \lambda_k V_k, \quad (6)$$

where λ_k is the k-th eigenvalue (variance of the k-th component), and V_k is the corresponding k-th eigenvector (component coefficients).

The next task is to calculate factor loadings, which show the depth of the relationship between variables and components, according to the following formula [10]

$$Load_{jk} = V_{jk}\sqrt{\lambda_k}. \quad (7)$$

The final task of the stage is the interpretation of principal components, where each component has its own name.

The stage of calculating integral estimates. At this stage, the results of the principal component method are converted into formal numerical estimates. At this stage, several tasks are set.

The first of them is the calculation of factor estimates [10]

$$F_{ik} = \sum_{j=1}^{p} w_{jk} z_{ij}, \quad (8)$$

where z_{ij} is the standardized value, w_{jk} is the weights (component coefficients).

The next task is the normalization of the integral estimate, for which linear normalization is applied [10]

$$R_i = \frac{F_i - F_{\min}}{F_{\max} - F_{\min}}. \quad (9)$$

The final task of the stage is the interpretation of the results.

In the study, when processing the results from assessing the level of development of scientific and pedagogical competencies, a DESKTOP-HQMOL6N PC, Intel(R) Celeron(R) processor (USA), 8.00 GB RAM, Intel(R) Graphics 600 (128 MB) graphics card (USA) were used. The results were calculated using the Python programming language (The Netherlands).

5. Results of improving the generalized approach to assessing the level of development of scientific and pedagogical workers' competencies section title

5. 1. Improving the methodology for assessing the level of development of scientific and pedagogical workers' competencies

The basic assessment methodology was chosen as the assessment methodology [7], which is based on the exclusion of repeated indicators from the criteria and the corresponding adjustment of the sum of points that will be issued for one or another integral criterion.

The improved methodology for assessing the level of competence development of HMEI SPWs consists of seven consecutive and coordinated stages.

The stage of forming a list of competencies, the level of development of which must be assessed. At this stage, a system of competencies is formed as a hierarchical model, where at the metalevel there are generalized competencies, at lower hierarchical levels there are blocks of competencies and blocks of component competencies.

Based on previous scientific research [11, 12], the structuring of competencies of HMEI SPWs was carried out according to their sources of origin.

The general hierarchical structure of competencies is shown in Fig. 1.

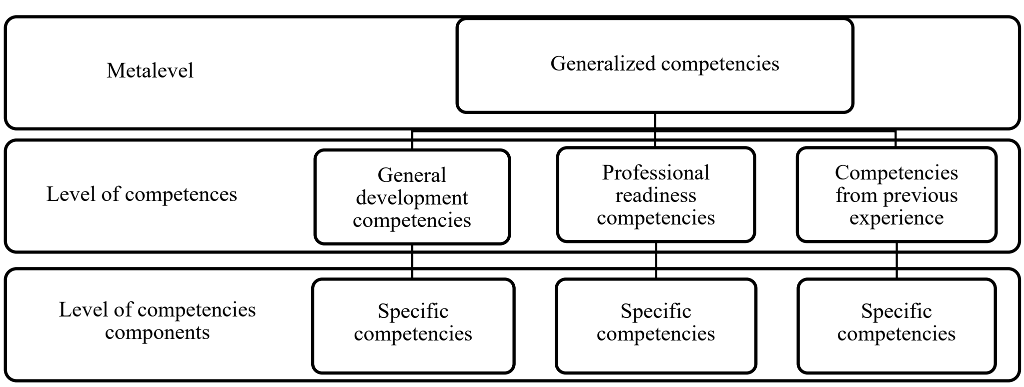

Fig. 1. General hierarchical structure of competencies

This structure takes into account the features of competencies, creates hierarchical levels of competencies of lower levels, reveals signs of their systematicity.

Stage of substantiation of indicators. At this stage, a set of indicators is established, through which the level of competence formation is directly or indirectly reflected. Criteria for measuring each indicator for further statistical processing are also established.

Also at this stage, the following are carried out:

1) initial testing of indicators using expert assessment (10–15 experts);

2) analysis of content validity;

3) calculation of Cronbach's alpha coefficient (Cronbach's $\alpha \geq 0.7$) [13];

4) verification of inter-indicator correlations [14].

Stage of sample formation and data collection. At this stage, the category of HMEI SPW to be evaluated and a representative sample are determined, which should reliably reflect the structure of the general population.

In order to obtain a true picture of the general population, the sample population must represent (according to a number of selected parameters) a model of the object and reflect the general population in its main qualitative and quantitative characteristics, that is, be representative. Ensuring proper representativeness of the sample and results is one of the most important factors in the effectiveness of research and the basis for making effective management decisions based on research results [15].

The collection of quantitative and qualitative data was carried out by directly assessing the level of competence development and obtaining information about HMEI SPWs in the personnel service and from the heads of structural units.

The construction of the primary observation matrix was carried out by arranging the collected data into the structure:

$$X = \left[x_{ij}\right],$$

$$i = 1..n,$$

$$j = 1..p, \quad (10)$$

where x_{ij} is the value of the j-th indicator for the i-th HMEI SPW, n is the number of respondents, p is the number of indicators.

Data quality control was carried out according to the following procedures. Identification of omissions that may occur due to incomplete filling in questionnaires, unavailability of portfolio data or insufficient awareness of the expert. Checking for extreme values using boxplot analysis [16], standard deviations, or Grubbs test [17]. Checking the distribution of indicators using Shapiro-Wilk tests [18], Kolmogorov-Smirnov [19], or QQ-plot graph [20]. Checking for multicollinearity [21], which can distort the obtained results, using the methods of correlation matrix, VIF (variance inflation factor) [22], or determinant of R [23].

The conditions for the suitability of data for the principal component method were checked using the Kaiser-Meyer-Olkin coefficient (hereinafter referred to as KMO) [24], in which KMO > 0.6 is acceptable, KMO > 0.8 is good, KMO > 0.9 is excellent.

Thus, at the stage of sample formation and data collection, the basis for further mathematical modeling was formed. The validity of the principal components, the interpretability of factors, the reliability of the integral rating, and the possibility of generalizing the results depend on the correctness of data collection.

The stage of statistical data preparation and selection of the variance matrix. At this stage, several tasks were set. The first of them was the determination of the centering of variables, which was carried out by subtracting the average value of each indicator (2).

The data were also transferred to a coordinate system where the center of mass is at the point (0,0,…,0).

The next task of the stage was data standardization

$$Z_{ij} = \frac{xX_{ij} - xX_j j}{S_j j}, \quad (11)$$

where the standard deviation of the j-th indicator is

$$s_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij}\right)^2}. \quad (12)$$

By standardizing the data, the dominance of indicators with large values was eliminated, which is a prerequisite for the principal component method.

The next task is to check for multicollinearity, which is carried out using correlation matrix methods, where $|r| > 0.80$ is a strong risk of collinearity. The VIF method (hereinafter referred to as VIF) can also be used, where VIF > 5 is undesirable, VIF > 10 is critical. Or the determinant of correlation matrix method, where under the condition det $(R) \rightarrow 0$, the matrix is degenerate.

The next task of the stage is to measure the degree of suitability of data for factorization using the KMO test

$$\text{KMO} = \frac{\sum r_{ij}^2}{\sum r_{ij}^2 + \sum p_{ij}^2}, \quad (12)$$

where r_{ij} – correlations, p_{ij} – partial correlations.

The next task is to choose the type of dispersion matrix (correlation or covariance matrix).

It is noted that the correlation matrix [25] can be used when the indicators have different scales; there are point, rating, interval scales and there is a significant amount of mixed data.

In turn, the covariance matrix [26] can be used when all variables are measured in the same units and real values of dispersions are important.

So, the result of the stage is data standardization, elimination of multicollinearity, confirmation using data suitability tests and selection of the dispersion matrix. These components are defined as the conditions for further application of the principal component method [26].

Stage of application of the principal component method. At this stage, hidden components are identified, with the help of which the structure of the competencies of HMEI SPWs is described.

This stage includes several tasks.

The first of these is the construction of a correlation or covariance matrix, which is denoted

$$R = \left(r_{ij}\right) \text{ or } C = \left(c_{ij}\right). \quad (13)$$

Such a matrix was defined as the basis for the next step, namely spectral decomposition, in which the problem was solved using the principal component method

$$Rv_k = \lambda_k V_k, \quad (14)$$

where λ_k is the k-th eigenvalue (variance of the k-th component), and V_k is the corresponding k-th eigenvector (component coefficients).

It is noted that the eigenvectors are the directions of the greatest variability of the data, and the eigenvalues are the "weight" of each direction.

The next task is to determine the number of principal components. In this process, the minimum number of K components is selected, which are retained for dimensionality reduction and further analysis.

The selection of the minimum number of K components involves the use of several criteria, namely the cumulative share of explained variance criterion [27], the Kaiser criterion [28], and the scree criterion [29].

Thus, in the case of choosing the cumulative share of explained variance criterion, K components are selected so that the sum of the variances covers the desired percentage (80%)

$$K = \frac{\sum_{k=1}^{K} \lambda_k}{\sum_{i=1}^{p} \lambda_i} \geq 0.80. \quad (15)$$

This criterion is used separately if there are clear requirements for preserving information not lower than a certain percentage [27].

When the Kaiser criterion is selected, only those components that are more informative than one individual standardized variable is retained. Only those principal components whose eigenvalues λ_k are greater than or equal to one are also selected [28].

In the standardized data, each initial variable has a variance equal to one. If a component has an eigenvalue less than one, it explains less variance than one individual variable and is therefore considered insufficiently informative for inclusion.

If the Kaiser criterion gives the number of components that collectively exceed the required variance threshold, a smaller number of components is selected, focusing on the criterion of the cumulative proportion of explained variance. Conversely, in the case of fewer components than the variance threshold requirements, the methodology is revised or the threshold is increased, given that each added component already explains less than one variable [28].

In the case of choosing the option of using the specified criteria together, the Kaiser criterion was applied to obtain the initial set of K components. Subsequently, a check was carried out to explain a sufficient cumulative share of the variance at the level of a percentage value not lower than the specified one, and the solutions found were confirmed using the scree criterion.

The essence of the scree criterion (Scree Plot) is to graphically display the eigenvalues λ_k (the variance explained by each component) against the serial number of this component, determining the "break" point on the eigenvalue graph [29].

The next task of the stage was to calculate the factor loadings, which show the depth of the relationship between variables and components, according to the following formula

$$Load_{jk} = V_{jk}\sqrt{\lambda_k}. \quad (16)$$

The data obtained as a result of the calculations explained the relationship, where || > 0.7 – strong relationship, || > 0.5 – moderate relationship, || < 0.3 – weak relationship [29].

The next task was to rotate the components in order to increase the interpretability of the model, creating clear blocks of competencies.

The final task was to interpret the main components, where each component received its own name, which is based on the indicators with the highest loads.

The stage of calculating integral estimates based on the evaluation results. At this stage, the results of the principal component method were converted into formal numerical estimates of the level of development of competence by each HMEI SPW. This stage implies the implementation of several tasks.

The first of them was to calculate factor estimates for each HMEI SPW

$$F_{ik} = \sum_{j=1}^{p} w_{jk} z_{ij}, \quad (17)$$

where z_{ij} is the standardized value, w_{jk} is the weights (component coefficients).

The next task is to build an individual competency profile for each HMEI SPW, which includes factor estimates, integral indices, and diagrams of the "radar" or "spider web" type [30].

The next task is to normalize the integral estimate, for which linear normalization is used

$$R_i = \frac{F_i - F_{\min}}{F_{\max} - F_{\min}}, \quad (18)$$

or conversion to a 100-point scale.

The final task is the interpretation of competence indices, where 90 m 100 is a high professional level, 70–89 is a sufficient level, 50–69 is an average level, and <50 is a low level [30].

The final stage is the formation of a rating. At this stage, statistical results are transformed into a management decision-making system.

At this stage, the rating of HMEI SPWs is formed on the basis of an integral index

$$S_i = \sum_{k=1}^{m} \alpha_k F_{ik}, \quad (19)$$

where a_k – component weights (dispersion fraction).

A general flowchart of the methodology for assessing the level of competence development of HMEI SPWs is shown in Fig. 2.

Thus, maximum objectivity and accuracy in assessing the level of competence development of HMEI SPWs is ensured by using an improved methodology based on the application of the principal component method (Fig. 2).

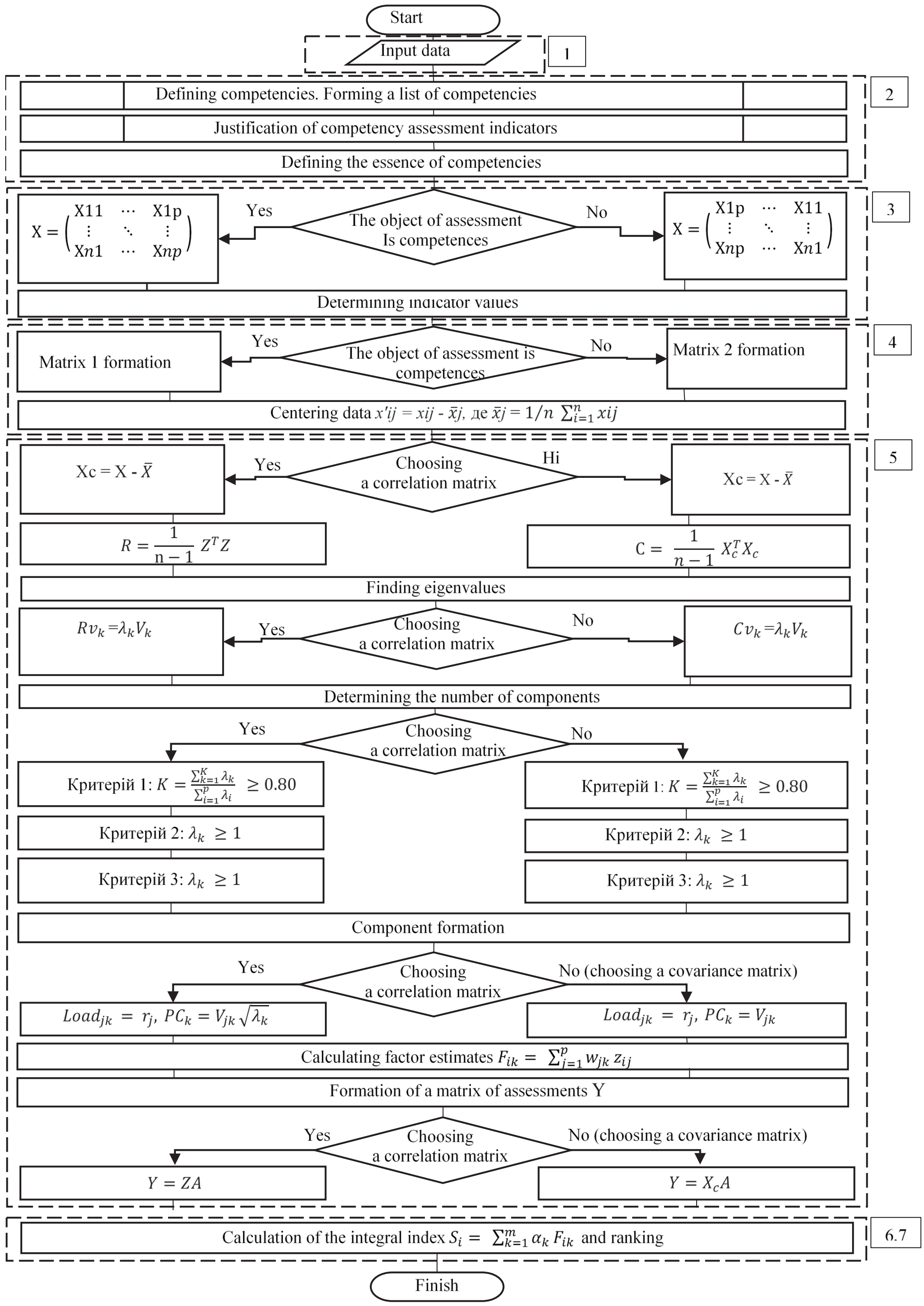

Fig. 2. General flowchart of the methodology for assessing the level of competence development

5. 2. Improving the procedure for assessing the level of development of scientific and pedagogical workers' competencies

5. 2. 1. Practical procedure for assessing the level of development of scientific and pedagogical workers' competencies

The procedure for assessing the level of development of scientific and pedagogical workers' competencies of HMEI SPWs consists of several consecutive stages.

Thus, at the stage of forming the list of competencies, the level of development of which needs to be assessed, a list of competencies of general development, professional preparedness, and previous practical experience was formed.

At the stage of substantiation of indicators, by means of which the level of development of selected competencies will be assessed, assessment indicators were determined and criteria for their measurement were established. For the initial testing of indicators, the calculation of the Cronbach's Alpha coefficient was chosen.

At the stage of sample formation and data collection, military personnel in military service at HMEIs on similar SPW positions were selected.

The collection of quantitative and qualitative data was carried out by obtaining information from the personnel service and from the heads of structural units and directly assessing the selected competencies through surveys, questionnaires, and tests.

The construction of the primary observation matrix was carried out by arranging the collected data into a matrix. Subsequently, data quality control and verification of the conditions of their suitability were carried out in accordance with the assessment methodology.

At the stage of statistical data preparation and selection of the dispersion matrix, data standardization, elimination of multicollinearity, confirmation of data suitability, and selection of the dispersion matrix were carried out. To check for multicollinearity, one of the methods specified in the assessment methodology was selected.

Subsequently, the degree of data suitability for factorization was measured using the KMO test. Since the obtained results of the assessment of competencies have different units of measurement, a correlation matrix was selected.

At the stage of direct application of the principal component method, a correlation matrix was built, which reflected the strength and direction of the relationships between all indicators and made it possible to formalize the structure of dependences between variables.

Subsequently, a spectral decomposition of the correlation matrix was performed, as a result of which the eigenvalues and the corresponding eigenvectors were determined. Next, the number of principal components to be preserved was determined using the criterion of the cumulative share of explained variance.

After determining the number of principal components, factor loadings were calculated, which characterize the degree of influence of each indicator on the corresponding component. Only those loadings were included in the interpretation, the modulus of which makes it possible to highlight the most significant relationships.

In order to increase the interpretability of the results, the components were rotated to form clear and meaningfully interpreted groups of indicators that correspond to individual latent factors.

At the final step, the interpretation of the obtained principal components was carried out. Each component was assigned a meaningful name in accordance with the indicators that have the largest factor loadings.

At the stage of calculating integral estimates, results from the principal component method were converted into formal numerical estimates of the level of competence development of each HMEI SPW.

At the final stage, the statistical results were transformed into a rating of HMEI SPWs for making a well-founded management decision.

5. 2. 2. Substantiating the effectiveness of the practical procedure for assessing the level of competence development of scientific and pedagogical workers

To substantiate the effectiveness of the practical procedure for assessing the level of competence development of HMEI SPWs, it is proposed to consider an example.

Initial data of the example. The basis of the example is HMEI. The sample includes military personnel from among the officers who are in the military service as senior lecturers at departments and teach general military disciplines. The stay of officers in the SPW positions is not less than two and not more than five years.

The competencies selected for assessment include 6 competencies:

Competence 1 is the basic knowledge in various fields. This competence is understood as a set of knowledge, skills, and abilities that allow an individual to think effectively, learn, understand the world around them, and solve problems, as an indicator of the level of development of a person's mental abilities.

Competence 2 is the ability to maintain self-control in stressful situations, under pressure, and under conditions of uncertainty. This competence is understood as a set of knowledge, skills, and abilities that allow a person to understand, manage, and express their emotions, as well as to understand and respond effectively and constructively to the emotions of other people.

Competence 3 is the fundamental knowledge of theories, concepts, and principles in their subject area. This competence is understood as in-depth knowledge of the subject area (discipline), as well as knowledge in the field of pedagogy and teaching methodology, which are necessary for the effective implementation of scientific research and pedagogical activities.

Competency 4 is the ability to combine traditional and innovative methods to achieve educational goals. This competency refers to the ability to effectively apply relevant digital tools, platforms, resources, and innovative pedagogical approaches to organize and conduct educational activities.

Competency 5 is the ability to recognize the individual goals of each team member. This competency refers to the ability to create a work environment in which employees feel intrinsic motivation, involvement and desire to perform professional duties qualitatively, strive for development and success in their work.

Competency 6 is the ability to generate new ideas for solving problems. This competency refers to the ability to go beyond templates when solving problems and making decisions, as well as the desire to improve the quality of work, improve professional skills, and achieve the best results.

Indicators by which the selected competencies are assessed.

For the assessment of Competency 1 – a is "number of educational institutions where training took place" and *b* is a "mean score in the diploma supplement (on a 5-point scale)".

For the assessment of Competency 2 – c is the "results of the Perceived Stress Scale test".

For the assessment of Competency 3 – d is a "grade for professional (vocational) training for the last assessment of service activities (on a 5-point scale)".

For the assessment of Competency 4 – e is an "average assessment of students' satisfaction with the combination of traditional and innovative methods (on a 10-point scale)".

For the assessment of Competency 5 – i is the "assessment of the activity performed by the applicants (on a 10-point scale)" and e is the "assessment of the satisfaction of the students with the combination of methods (on a 10-point scale)".

For the assessment of Competency 6 – f is the "results of the Divergent association task test".

For the initial testing of the indicators, the calculation of the Cronbach's Alpha coefficient was chosen.

Thus, at the data collection stage, the collection of quantitative and qualitative data was carried out by obtaining information from the personnel service and surveying education seekers and testing military personnel from the sample.

Subsequently, an initial observation matrix was built by filling it with the obtained data.

Using specialized software, the corresponding calculations were performed, and a rating of military personnel was formed.

The generalized results of competency assessment are given in Table 1.

Table 1

Summary of competency assessment results

Respondents	Competencies and their assessment results							
	1		2	3	4	5		6
	a	b	c	d	e	i	e	f
officer 1	3	3.7	7	5	8	7	8	81
officer 2	2	4.2	18	4	7	8	7	77
officer 3	2	4.3	32	5	9	7	9	75
officer 4	3	3.9	10	5	8	9	8	77
officer 5	2	4.4	22	4	8	7	8	82
officer 6	2	4.5	16	4	7	9	7	78

Based on calculations based on simple evaluation results without taking into account internal correlations, a rating of military personnel was formed, which is given in Table 2.

Table 2

Rating of military personnel without taking into account internal correlations

Position in the ranking	Respondent	Average score (Z value)	Interpretation of results
1	Officer 1	0.92	Consistently high scores on all criteria
2	Officer 3	0.51	Moderate results with an emphasis on professional activity
3	Officer 4	0.38	Average level on most indicators
4	Officer 5	0.26	Close to the sample average
5	Officer 2	–0.62	Below average (impact of high stress levels)
6	Officer 6	–1.45	Critically low scores on professional training

To compare the data, based on the results built on the basis of taking into account internal correlations, a rating of military personnel was formed, which is given in Table 3.

Using our results, it was argued that taking into account internal correlations gives more accurate assessment results with the same rating construction.

In order to substantiate the effectiveness of the improved methodology for assessing competencies, the results of assessing one competency from the general development block and one competency from the previous practical experience block were artificially ch anged. The results of assessing professional readiness competencies did not change.

The generalized results of assessing competencies are given in Table 4.

Table 3

Rating of military personnel taking into account internal correlations

Position in the ranking	Respondent	Average score (Z value)	Main component
1	Officer 1	1.08	Balanced (professional activity + creative)
2	Officer 3	0.54	Predominantly professional activity
3	Officer 4	0.28	Biased towards creativity
4	Officer 5	0.21	High creativity with low training
5	Officer 2	–0.76	Deficit in both vectors
6	Officer 6	–1.35	Systemic non-compliance with criteria

Table 4

Summary of competency assessment results

Respondents	Competencies and their assessment results							
	1		2	3	4	5		6
	a	b	c	d	e	i	e	f
officer 1	3	3.7	22	5	8	7	8	74
officer 2	2	4.2	18	4	7	8	7	77
officer 3	2	4.3	32	5	9	7	9	75
officer 4	3	3.9	10	5	8	9	8	77
officer 5	2	4.4	7	4	8	7	8	82
officer 6	2	4.5	16	4	7	9	7	78

Based on the results of calculations without taking into account internal correlations, carried out after making changes to the results of the competency assessment (Table 4), a rating of military personnel was formed, which is given in Table 5.

To compare the data, based on the results of calculations taking into account internal correlations, a rating of military personnel was formed, which is given in Table 6.

Table 5

Rating of military personnel without taking into account internal correlations

Position in the ranking	Respondent	Average score (Z value)	Interpretation of results
1	Officer 3	0.69	High stability of professional indicators
2	Officer 4	0.34	Moderate results in all vectors
3	Officer 2	0.16	Average level of training
4	Officer 1	–0.05	Reduction in position due to high level of stress
5	Officer 5	–0.26	Low indicators of professional training
6	Officer 6	–0.88	Systemic lag in most parameters

Table 6

Rating of military personnel taking into account internal correlations

Position in the ranking	Respondent	Average score (Z value)	Changing positions
1	Officer 3	0.82	0 (stable leader)
2	Officer 4	0.28	+1 (risen higher)
3	Officer 2	0.18	–1 (ceded position)
4	Officer 1	–0.12	0
5	Officer 5	–0.31	0
6	Officer 6	–0.85	0

Our results show that the change in the positions of officers in the rating occurred as a result of taking into account internal correlations. Officer 2 rose in the rating by one position. and Officer 4, respectively, fell by one position.

That became possible due to the consideration of the results of the assessment of general development competencies and previous practical experience. At the same time, the results of the assessment of professional readiness competencies, which are key in the existing methodology, remained unchanged.

Thus, the objectivity of the assessment conducted using the improved procedure increased by 16.6%, which, in turn, indicates effectiveness of the improved methodology.

6. Discussion of results based on the improved approach to assessing the level of development of scientific and pedagogical workers' competencies

Our study has improved the methodology for assessing the level of competence development of HMEI SPWs.

Unlike [2–5], in which simple averaging of the evaluation results was used in the competence assessment methods, the improved methodology (Fig. 2) makes it possible to eliminate multicollinearity and take into account connections between competencies.

That became possible due to the use of the principal component method in the assessment methodology. Thus, unlike the rating built on the basis of simple averaging (Table 5), the evaluation results (Table 6) demonstrated the distribution of officers according to two principal components.

Analysis of the rating of officers in the space of two principal components (Table 6) revealed their hidden potential, which was leveled when using simple averaging of the evaluation results (Table 5). In particular, Officer 1, despite the high level of stress (Table 4), maintained the leading position according to the average assessment results.

Along with the above, one of the key problems described in [7, 8] is the duplication of indicators. Analysis of the original data in Table 4 confirmed the presence of strong relationships between professional training and responses of education seekers. The use of the principal component method made it possible to combine these dependent variables into one component, eliminating multicollinearity, which prevented the artificial overestimation of the weight of individual assessments, which is observed with simple averaging of assessment results (Table 5).

The study also improved the procedure for assessing the level of competence development of HMEI SPWs.

Unlike [6–10], in which simple averaging of assessment results was used in the competence assessment procedures, the improved procedure used an improved methodology and ensured maximum objectivity and accuracy in assessing the level of competence development.

The main argument in favor of using the principal component method was the discrepancy in the rating results compared to the traditional procedure. As evidenced by the data (Tables 2, 5), a rating based on the sum of the scores was constructed by simply averaging the evaluation results without taking into account internal correlations.

However, when taking into account internal correlations (Tables 3, 6), a change in the positions of officers was revealed. In particular, the change in the positions of Officer 2 and Officer 4 in the rating (Tables 5, 6) proved that the principal component method better identified the qualitative structure of competencies.

In addition, our study confirmed the importance of the hierarchical structure of competencies of HMEI SPWs (Fig. 1).

The improved methodology and assessment procedure are of direct importance for personnel management at HMEIs. Taking into account the results obtained using the improved methodology (Table 6), it ensured the adoption of justified management decisions and created conditions for accurate prediction of the effectiveness of HMEI SPWs in the long term.

The following limitations of our study were established.

The limits of application of the improved methodology is the assessment of the level of development of SPW competencies at HMEIs. The condition for applying the improved procedure is a high level of preparedness of the personnel conducting the assessment. The reproducibility of the results, resistance to changes in influencing factors, ranges of input data within which the obtained results are determined to be adequate and reproducible, leading to the declared effects.

The disadvantage of the study is the small number of respondents in the group, which limits the possibility of qualitative testing of the hypothesis put forward on a large sample. However, our results confirm that ignoring internal correlations led to the loss of important information and a biased assessment of the level of competence development.

Future studies could involve experimental testing of the improved procedure for assessing the level of competence development in accordance with the improved methodology on an increased number of respondents with an increased number of competencies and indicators for their assessment.

7. Conclusions

1. We have improved methodology for assessing the level of competence development of HMEI SPWs.

Unlike conventional methodologies, which use simple averaging of assessment results, the improved methodology employs the principal component method. This feature has made it possible to solve part of the general problem, in particular, regarding the elimination of multicollinearity and taking into account connections among competencies.

2. A procedure for assessing the level of competence development of HMEI SPWs has been improved by using an improved methodology applying the principal component method, which has made it possible to increase the objectivity and accuracy of the assessment by 16.6%. This feature has made it possible to solve part of the general problem, in particular, regarding simple averaging of assessment results.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Authors' contributions

Oleksandr Maistrenko: Project administration, Methodology; **Denys Sysolyatin**: Conceptualization, Writing – original draft; **Volodymyr Kurban**: Resources, Supervision; **Oleksandr Karavanov**: Formal analysis, Methodology; **Serhii Voitenko**: Software, Visualization; **Olha Babych**: Software, Visualization; **Andrii Diakov**: Validation, Data Curation; **Oleksandr Lykholot**: Writing – review & editing, Investigation; **Serhii Horbenko**: Investigation, Visualization; **Nataliia Rusenko**: Formal analysis, Resources.

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