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A model for improvement of methodological tools to foster undergraduate students' involvement in scientific research

Un modelo para mejorar las herramientas metodológicas para fomentar la participación de los estudiantes de pregrado en la investigación científica

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Contents

ABSTRACT:
This study aims to develop conceptual recommendations for improving the tools that introduce the principles of continuity and succession into the research activities of higher education students to increase the graduates' level of competitiveness. The Nosov Magnitogorsk State Technical University was used as a case study, and 321 students from this university were surveyed. A three-dimensional vector model of the students' research activities development was established.
Keywords: continuity principle, succession principle, scientific research, higher education.

RESUMEN:
Este estudio tiene como objetivo desarrollar recomendaciones conceptuales para mejorar las herramientas que introducen los principios de continuidad y sucesión en las actividades de investigación de los estudiantes de educación superior para aumentar el nivel de competitividad de los graduados. La Universidad Técnica Estatal de Nosov Magnitogorsk se utilizó como estudio de caso, y se encuestó a 321 estudiantes de esta universidad. Se estableció un modelo vectorial tridimensional del desarrollo de las actividades de investigación de los estudiantes.
Palabras clave: principio de continuidad, principio de sucesión, investigación científica, educación superior.

1. Introduction

Both the competitiveness of the Russian educational system and the development of society depend on the level and quality of the training of higher education students

(Asikainen & Gijbels, 2017; Dinsmore, 2017). The quality of the knowledge transfer from the educator to the student depends on the scientific, technological, and technical development of the society, appropriate policy decisions, the creation of the necessary scientific groundwork for the realization of future national interests, and the evolution of scientific thought (Rashchikulina et al., 2018).

Students' research activities have to be carried out continuously, taking into account their practical importance and the principle of succession. These activities form both scientific and general cultural competencies, which influence a person's readiness to act in non-standard situations, their willingness to bear social and ethical responsibility for the decisions they make, their propensity for self-development and self-realization, and their use of their creative potential (Russian Federation State Duma, 2012). Therefore, the aim of this paper is to develop conceptual recommendations to improve the tools necessary to implement the principles of continuity (the focus of all elements of the educational system on integral, evolving capabilities) and succession (establishing a connection between the past, present, and future in the process of continuous acquisition and expansion and the deepening and development of knowledge and skills on a higher scientific and practical basis) in students' research activities and increase the level of competitiveness in Russian universities. The question we sought to answer with this study was whether the key factors in the development of research activities have a direct connection to continuity and succession. The main pedagogical conditions for forming and developing the principles of continuity and succession are strongly supported (Ivanova, 2012). We developed a conceptual model to improve the theoretical and methodological tools for the development of research activities of undergraduate students based on the priorities of continuity and succession principles.

2. Literature review

Asikainen and Gijbels (2017) examined the skills and competencies among students that can influence the achievement of professional self-realization. Some scholars have concluded that the focus should be on the factors that influence the efficiency of research activities. Knyazeva (2017) highlighted the methodological and organizational factors that determine successful research activities. While according to Danilchenko (2015), the activities of the students are affected by strategic factors that reflect the importance of personal participation in obtaining the results of the study, Ilyina (2014) noted that the role of personal factors, such as the lack of free time and low motivation to engage in research activities, has not been sufficiently explored. Richardson (2017) argued that the primary methods of improving the quality of higher education and the development of students' research activities should be in line with students' priorities. This opinion is shared by Berger and Bubnova (2017), who claimed that the problem of the decrease in students' interest in higher education lies precisely in a lack of interest in research work as well as in the high workload of educational activities. Kyndt et al. (2015) studied the development of the educational system in higher education institutions through the prism of increasing motivation and demonstrated the gradual growth of personal motivation in the process of recruiting students into higher education. The authors insisted that the involvement of students in the research process should be considered as a motivational factor.

The problem of the low efficiency of the cooperation between students and educators in the development of implementing scientific thought is attracting increased attention. Fredricks et al. (2016) identified an increase in students' interest in scientific activities. While they attempted to delineate the range of reasons that affect the students' motivation, continuity, and succession were ignored. However, these principles are not systematic and cannot adequately influence the development process of students' research activities. To generate significant changes in the interaction between educators and students, which will boost the competitiveness of education in general and research activities in particular, the principles of continuity and succession should be considered.

3. Materials and methods

Trend models were built to determine the relationship between the indicators of the

development of the higher education system and research activities. The models were based on the results of an analysis of the dynamic changes of these indicators between 2013 and 2018. Additionally, the linear modeling method was used to predict further changes in the development of the higher education system, and a linear trend was used that described uniform change in performance over time (Rousseau et al., 2018).

The following parameters of the model line were considered:

1) Equation (functional dependence):

$$y = ax + b, \quad (1)$$

where y is a dependent variable (a variable whose value is predicted),
x is an independent variable (the serial number of the period),
a is the coefficient of an independent variable characterizing the magnitude of the increase in the next value of the time series and b is a constant term.

2) The magnitude of the accuracy of the approximation: R^2. $R^2[0,1]$ is the number that reflects the proximity of the trend line value to the data. The closer the value of this indicator to 1, the more reliable the trend line.

After considering several options for constructing models, a linear model was chosen based on the maximum value of the confidence value.

The study involved 321 students from G.I. Nosov Magnitogorsk State Technical University Institute for the Humanities who took courses in the 2017–2018 academic year. The respondents were selected using random sampling with a random draw, and the personal consent of the students regarding completing the questionnaire was obtained. This particular university became a regional support university in 2017, and most educational and research activities in this university are in the fields of pedagogy, psychology, and social work, which contributes to the students' high level of sensitivity and openness to innovations and comprehensive development. The study protocol was approved by the Ethical Committee of the St. Petersburg State University (reference no: D152X34). Ethical conditions for the anonymous questionnaires were ensured, and the voluntary participation of students was verified by their signing of the appropriate agreement № 329 G. I. Nosov Magnitogorsk State Technical University. Participant confidentiality was also assured. The participants gave informed consent; that is, they knew the purpose of the study and its measures.

Anonymous questionnaires (a method adopted from social studies) were used to identify the most significant factors influencing the research activities of the students of G.I. Nosov Magnitogorsk State Technical University Institute for the Humanities (Table 1). The results were used to systematize further the key principles for improving the competitiveness of students.

Table 1

Questionnaire "What is Important for Me in Research Activities"

N	Questions
1)	Activity rate in scientific research: 1. I take part in scientific research exclusively within the requirements of academic disciplines; 2. I take an active part in scientific research.
2)	Strategic factors that affect my scientific research: 1. The possibility of expanding the student's scientific and business connections by participating in research activities; 2. The possibility of expanding personal intellectual potential with the further development of innovative methods and technologies; 3. The possibility of obtaining financial remuneration through participation in grant programs as well as obtaining well-paid work in the future; 4. Focus on achieving strategic goals.
3)	Tactical factors that affect my scientific research: 1. The possibility of the practical application of acquired skills, abilities, and competencies; 2. Regular horizontal and vertical interaction with research actors; 3. The possibility of implementing one's own projects; 4. Sense of self-importance while studying due to the implementation of the supervisor's recommendations regarding the student's research work.

The choice of the survey method was based on the ability to consider the personal attitude of the students to a particular factor. The adequacy of the sociological survey sample was assessed according to the following formula (Ponto, 2015):

$$s = \frac{Z(p)^2 \cdot v \cdot (1-v)}{e^2}, \quad (2)$$

where *s* is the minimum sample size sufficient to ensure the representativeness of the research results;
Z(p) is a normal deviation. The permissible level of probability belief at which the results of a sociological survey can be considered representative and statistically significant is 90%. At this level the normalized deviation is 1.7;
p is probability belief; *v* is the sample's variation; and *e* is error's permissible.
The results were processed using factor analysis, which enabled us to determine the aggregate variables that affect the answers of the respondents. The initial data were systematized in a single table, including the answers to questions 1–8, and the students were divided into two subgroups (strategic factors SF1-4 and tactical factors TF1-4).
The corresponding indicators were calculated to assess the reliability of the questionnaire:
χ^2-Pearson (formula 3), dispersion coefficient (formula 4), and variation coefficient (formula 5; all the formulas are from Rousseau et al. (2018):

$$\chi^2 = \sum \frac{(n_i - n_i^{'})^2}{n_i^{'}}, \quad (3)$$

where χ^2 is the calculated value of χ^2-Pearson,
n_i is the observed frequency in each category, and
$n_i^{'}$ is the expected frequency.

$$\sigma^2 = \frac{\Sigma(x_i - \bar{x})^2}{n}, \quad (4)$$

where σ^2 is the dispersion coefficient,
x_i is the value of the priority score of the factor,
$\overline{x}$ is an average priority for all criteria, and
n is the number of criteria.

$$v = \frac{\sigma}{\bar{x}} * 100\%, \quad (5)$$

where v is the assessments variation factor,
σ is the standard deviation of factor materiality, and
$\bar{x}$ is the arithmetic mean value of the factor.

While compiling the questionnaire, we were guided by the following criteria:
1) Indicator (factor, statement) representativeness—how much each indicator (factor, statement) influences the development of students' research activities;
2) Sufficiency—whether the proposed list of indicators (factors, statements) is sufficient to characterize the level of students' research activity development and the factors that influence it.
In order to assess the representativeness, the experts were asked to assess each factor regarding whether this (strategic and tactical) factor effects the development of students' research activities (answer options "Yes"/"No"). The assessment resulted in 92.5% positive responses, which indicates the consistency of the experts' opinions.
To prove the statistical significance of these factors, the χ2-Pearson criterion (formula 3) was used. The results of the factor representativeness assessment were grouped by tactical and strategic factors, highlighting the percentage of "Yes" answers (which means that the [strategic or tactical] factor influences students' research activities) and the percentage of "No" answers. The χ2-Pearson criterion was calculated for these two samples. The estimated value of 23.7 exceeds the tabular value of 3.84, which indicates the statistical significance of the influence of the proposed tactical and strategic factors on the students' research activities.

In assessing the factor sample sufficiency, the experts ranked it from 0 to 5. The higher the score given by the experts, the higher the level of the sufficiency of the sample. The average percentage for sample sufficiency, calculated as the ratio of the sum of expert scores to the maximum possible, was 89.3%. If we draw a parallel with multidimensional factor analysis, the factorization rate of 80% is a quality criterion in factor analysis (Jolliffe, 2002). Proceeding from this assumption, a score of 89.3% for the indicator sample sufficiency can be considered sufficient in this expert assessment. The consistency of expert opinions in assessing the sample sufficiency is indicated by the dispersion coefficient value calculated by formula 4, the result of which was 0.91, and the variation coefficient value (formula 5), the result of which was 8.4%. The latter does not exceed 10% and, therefore, indicates the consistency of the expert assessments.

The degree of consistency of the students' opinions and the representativeness of the results obtained were evaluated using the coefficient of concordance (Ponto, 2015):

$$W = 12 \times \frac{s}{[m^2 \times (n^3 - n) - m \times t_e]}, \quad (6)$$

where m is the number of students,
n is the number of factors,
S is the sum of the squares of rank differences (deviation from the average), and
t_e is the sum of similar rank values.

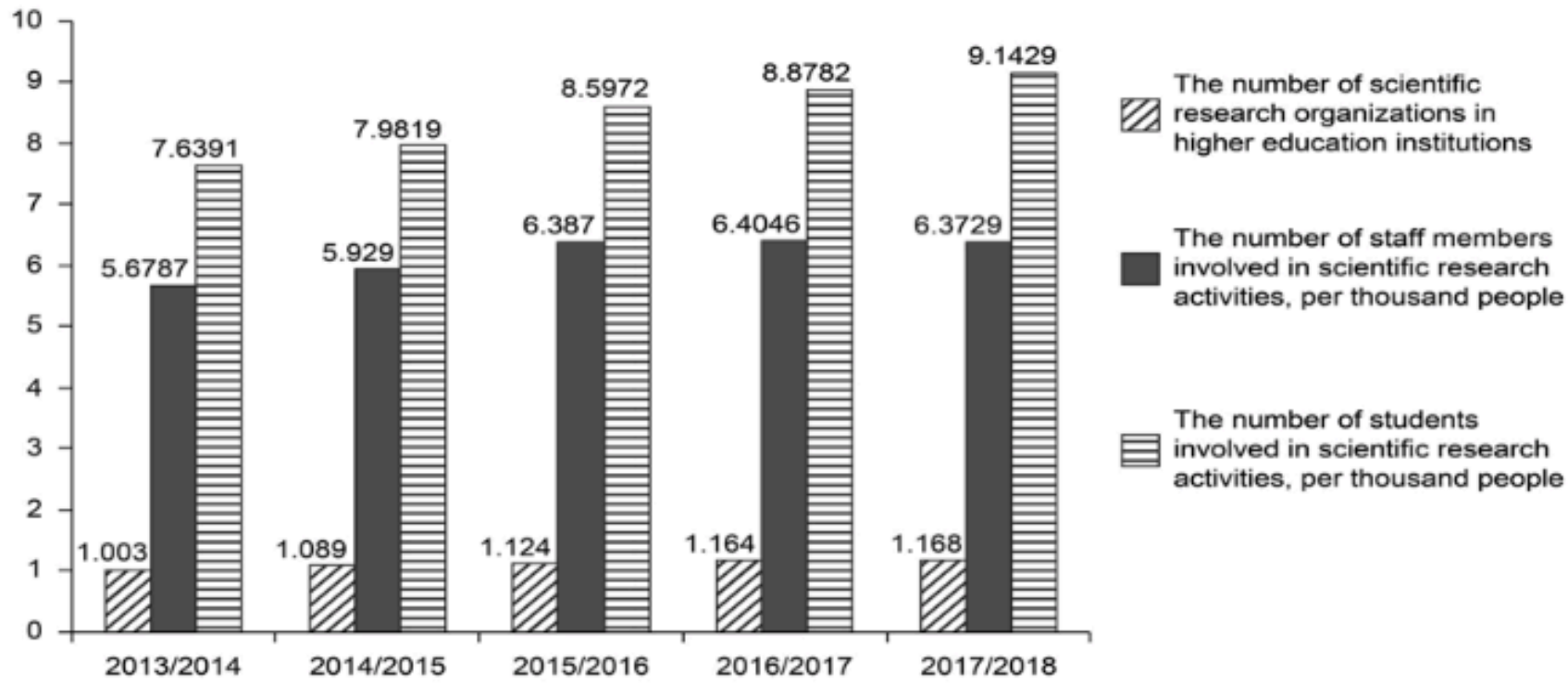
The coefficient of concordance can vary in the range of 1>W>0. At W = 0, there is no consistency of expert opinions, and at W = 1, the consistency is absolute. The consistency obtained for this study is high, at W≥0.5 (Ponto, 2015).

When completing the survey anonymously, the students were asked to rank the most significant factors influencing their participation and the efficiency of research activities. They used a four-point scale ranging from "0," which meant a complete rejection of the statement, to "4," which meant unconditional consent. The questionnaire also included an item on whether the student takes an active part in the scientific research of the university or participates in research only when doing so is mandatory. In addition, it was suggested that students take strategic or tactical factors into account. The question this study sought to answer was whether the key factors in the development of research activities have a direct connection with continuity and succession. The statistical significance of the students' results was proved by the rank correlation coefficient calculated by formula 6—the coefficient of concordance. The calculated value is 0.71 with a sufficiency level of 0.5, which indicates the consistency of the survey results and their representativeness. To build a model for the development of the students' research activities on the priority of the implementation of the principles of continuity and succession, a three-dimensional modeling method was used, which made it possible to outline the direction of improvement of the educational process in the form of vertices (Frischer & Dakouri-Hild, 2008). The following positions are taken as vertices: the principle of continuity, the principle of succession, and the factor of strategic perspective. The choice of vertices is based on the results of applying the previous methods.

4. Results

The study involved a comparative analysis of the dynamic changes in the number of research organizations in the field of higher education and changes in the number of students and lecturers involved in the research (Figure 1).

Figure 1
Dynamics of the Changes in the Number of Scientific Research Organizations in Higher Education in Comparison with the Number of Students and Lecturers Involved in Science

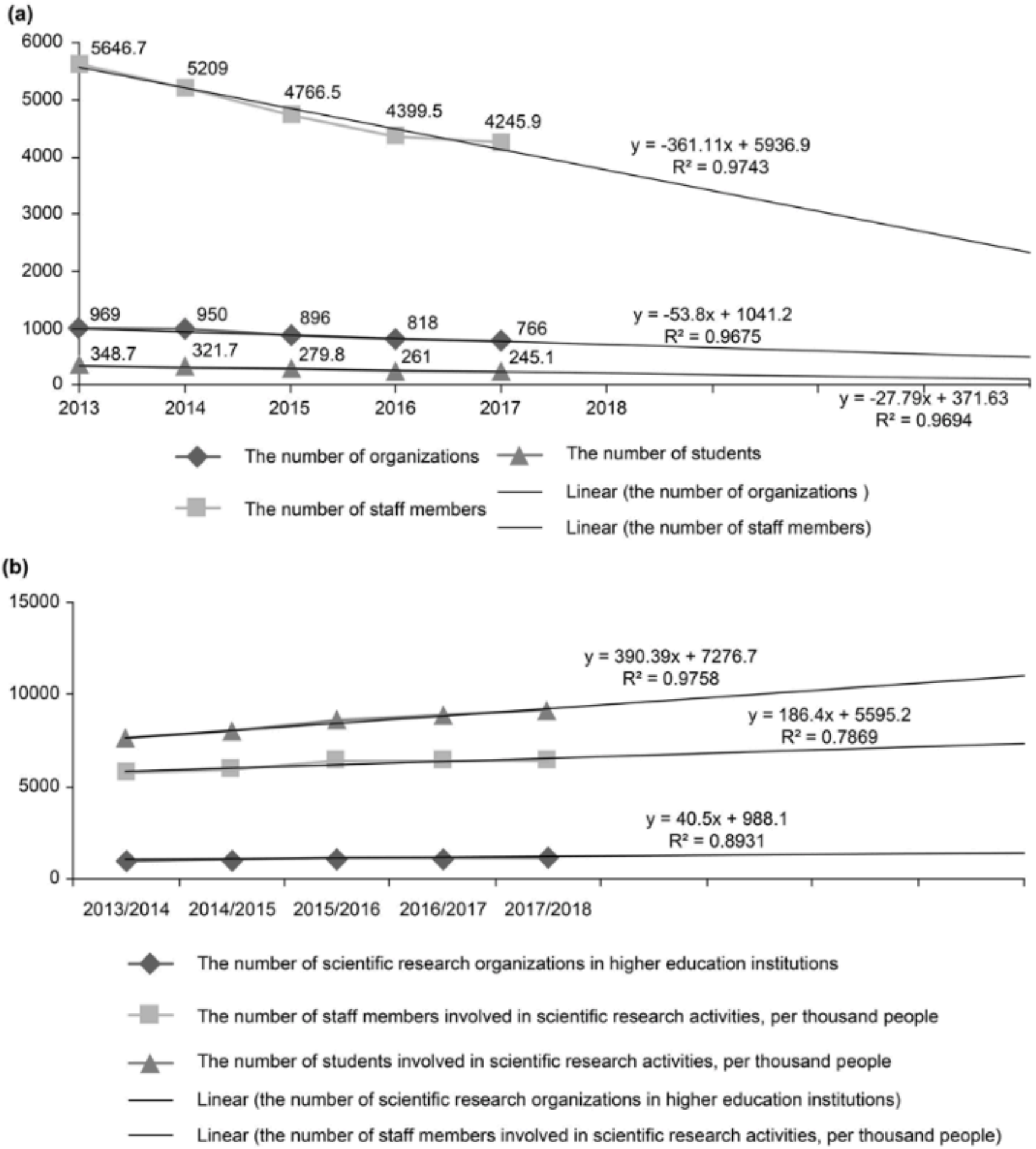


(Source: Federal Service for State Statistics, 2018)

The diagram reveals the positive dynamics of quantitative changes in the perspective of the system increase from the 2013/2014 to the 2017/2018 academic year in the number of scientific research organizations (by 16%), the number of staff members (by 12%), and the number of students involved in research activities during their university studies (by 19%). This demonstrated that there was an increase in the interest in scientific research activities in higher education. However, from the perspective of the quantitative

parameters of the development of the higher education system, a decrease in the indicators was observed. To reflect the relationship between the indicators of the development of the educational system of higher education and the development of research activities, trend models were built to predict further changes in the higher education system. Figure 2 reflects the projected decrease in the rate of the development of higher education. However, the obtained forecast model for the development of research activities in the higher education system based on the construction of a linear trend indicates a possible positive tendency.

Figure 2
Model of the Development of Higher Education in Russia in General (a), as Compared to the Development of Research Activities of Universities in Particular (b)

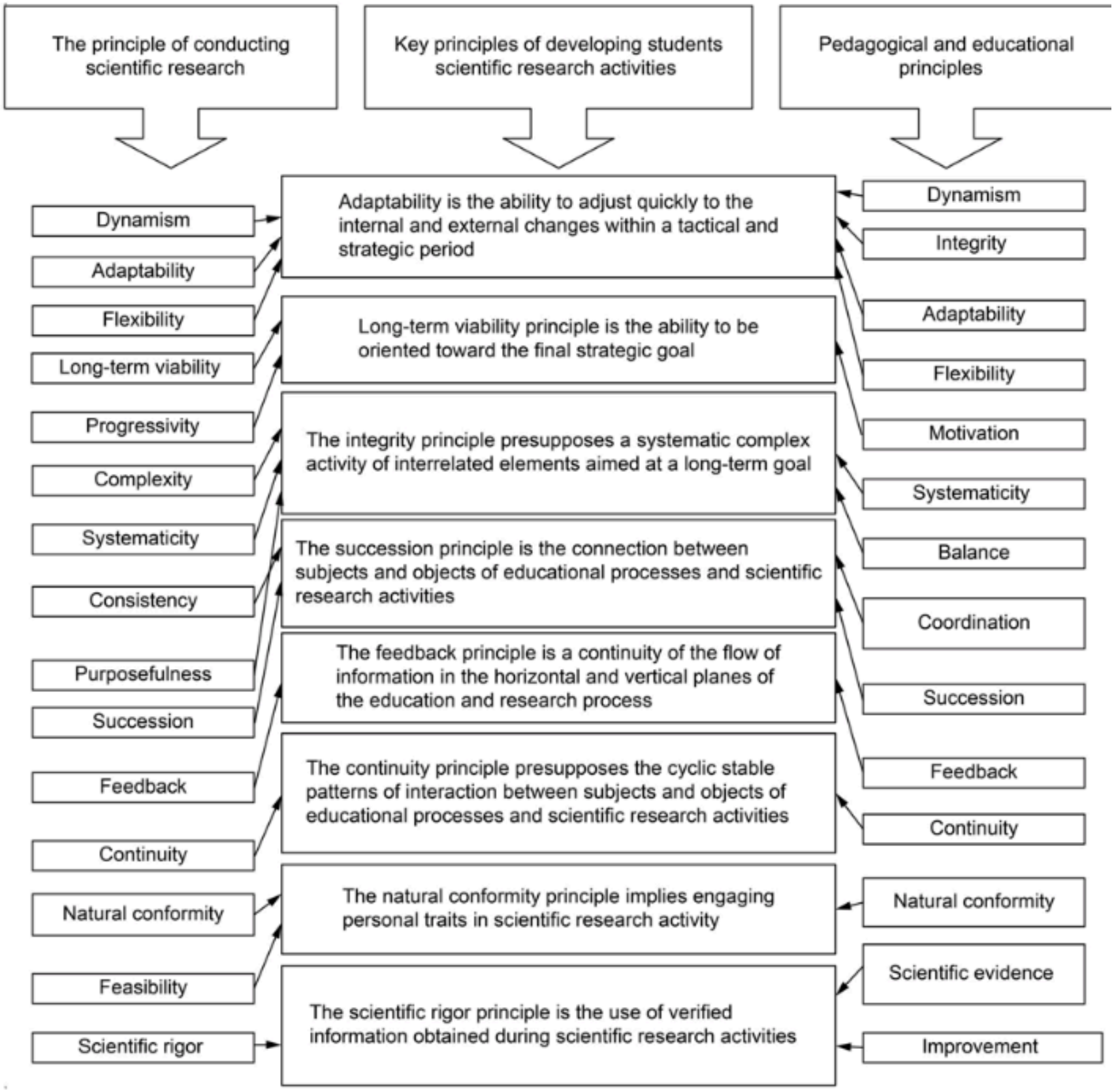


In the course of building trend models for the development of higher education in Russia in general, as compared to the development of scientific research activities in some universities in particular, it was found that with the reduction in the number of students, there was an increase in the number of students involved in research activities

(approximation R^2 in all of the models is close to 1, which indicates the adequacy of the results).

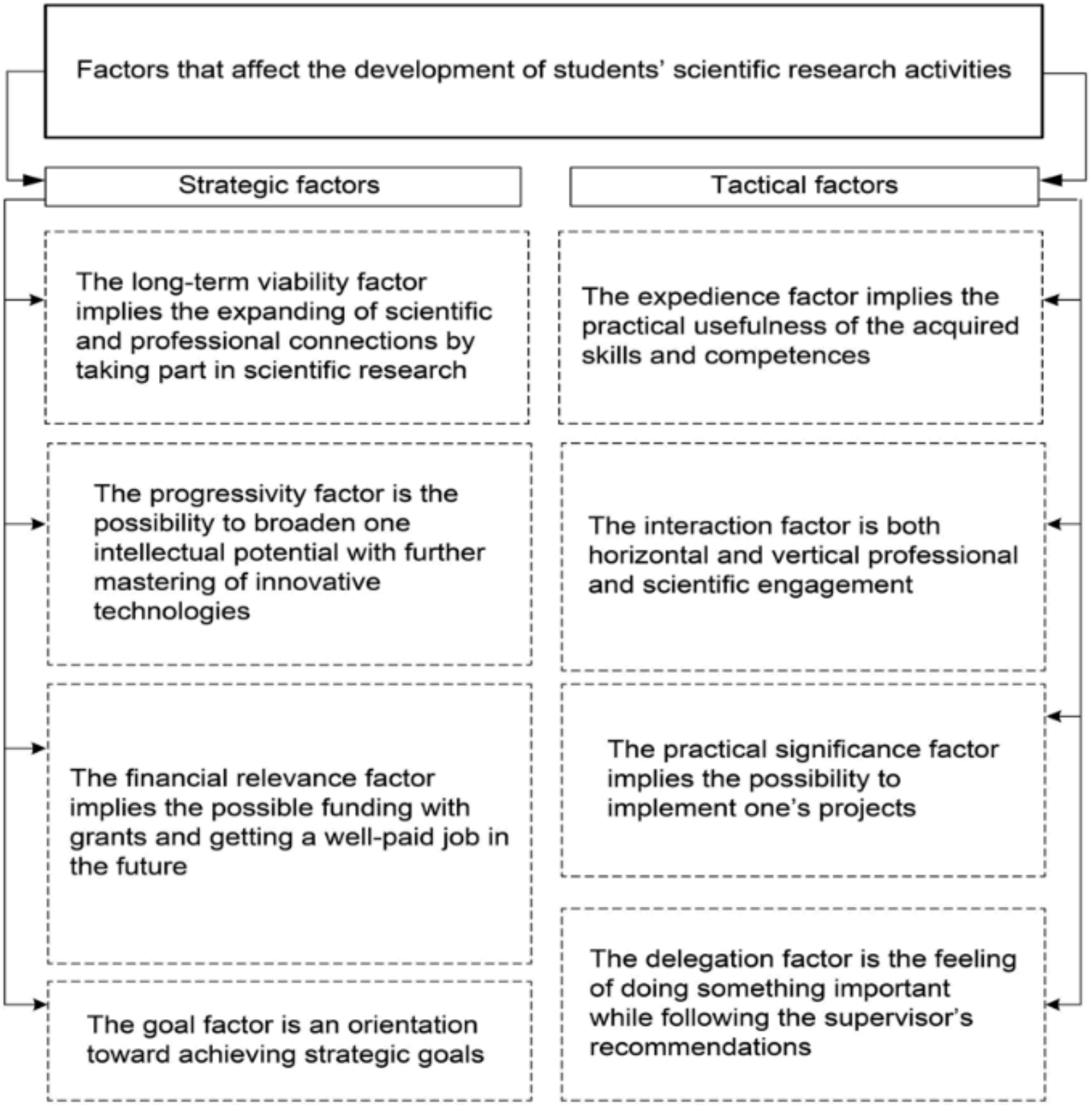
As the study revealed that the pedagogical conditions of students' involvement in the process of scientific research were insufficient (the evidence is based on the analysis of papers on the relevant subjects) the principles of research activity and the holistic educational process were determined by the method of generalization (Figure 3).

Figure 3
Systematization of the Principles in the Development of Student Research Activities



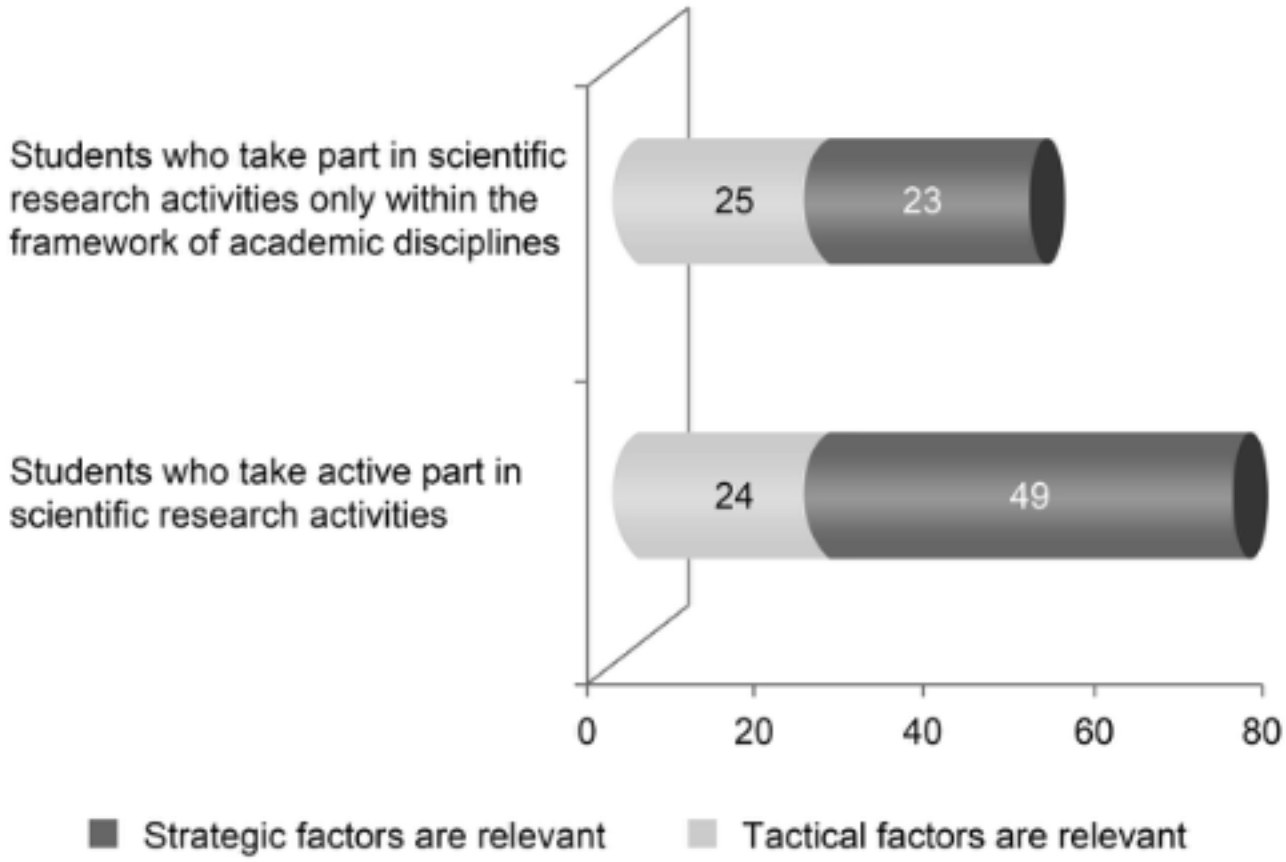
We found that both external and internal factors influence students' research activities. The main factors are shown in Figure 4.

Figure 4
Systematization of the Main Factors Influencing the Students' Development of Research Activities within the Tactical and Strategic Period.



The study revealed that students who participate in research activities in the framework of the educational process are equally affected by strategic and tactical factors (Figure 5).

Figure 5
Systematization of Students According to the Level of Their Involvement in Research Activities Based on the Results of the Survey



The results of the survey given to students from G.I. Nosov Magnitogorsk State Technical University Institute for the Humanities are presented in Table 2. As one of the questionnaire items was a question about how actively students are involved in research activities, the answers according to the significance of the factors were grouped into two subgroups. The first subgroup included the answers of respondents who indicated that they were actively engaged in research activities in their free time, showing an interest in scientific knowledge. The second subgroup of respondents consisted of students who did not show any special interest in participating in research activities, performing the minimum necessary tasks within the framework of their academic disciplines at the request of their lecturers.

The survey results are systematized in Table 1 in such a way that the answer option *a* of the questionnaire corresponds to Factor 1, *b* corresponds to Factor 2, *c* corresponds to Factor 3, and *d* corresponds to Factor 4.

Students who have a more active research role (the first subgroup) tend to be affected mainly by tactical factors. In particular, it was found that an interaction factor had the largest number of votes (49%), which indicates that teamwork between educators and students in the process of research activity, as well as between the students themselves, plays a substantial role. It should be noted that among the tactical factors, the delegation factor also proved significant (23%). The main point of this factor is the importance of the independent performance of key scientific tasks, the possibility of making decisions during the study, and the creation of conditions necessary for the manifestation of initiative in the development process. The factor of practical significance among students who are actively engaged in research activities ranked third (19%). This indicates that for some students, it matters whether the results of individual work will be published. The lowest ranking factor was the possibility of using their accumulated knowledge, skills, and competencies directly in the process of their work.

Table 2

Systematization of the Results of the Survey of the G.I. Nosov Magnitogorsk State Technical University Institute for the Humanities Students on the Determination of the Maximum Impact Factors That Affect the Development of Their Research Activities

Factor Number	Factor Name	Factor's Description	Students Actively Involved in Scientific Research, %	Students Involved in Scientific Research Only within the Framework of Academic Disciplines, %

Strategic Factors				
S1	Long-term viability factor (SF1)	Expanding scientific and professional connections by taking part in scientific research.	74	9
S2	Progressivity factor (SF2)	The possibility of broadening one's intellectual potential with further mastering of innovative technologies.	4	56
S3	Financial relevance factor (SF3)	The possible funding with grants and getting a well-paid job in the future.	21	32
S4	Goal factor (SF4)	Orientation toward achieving strategic goals.	1	3
Tactical Factors				
Ò1	Expedience factor (ÒF1)	Implies practical usefulness of acquired skills and competencies.	9	1
Ò2	Interaction factor (ÒF2)	Both horizontal and vertical professional and scientific engagement.	49	62
Ò3	Practical significance (ÒF3)	The possibility to implement one's projects.	19	3
Ò4	Delegation factor (ÒF4)	The feeling of doing something important while following their supervisor's recommendations.	23	34

Among the factors of strategic importance, most respondents singled out the factor of long-term viability, which is understood in this paper as the possibility of expanding their business and scientific connections as well as further employment through research activities (74%). The subsequent factor was financial relevance (21%), which, in addition to awards, incentives, and scholarships, also included paid participation in grant projects. If we carry out the interpolation of the results of tactical and strategic factors relevance, we can note the interrelation of the priority factors.

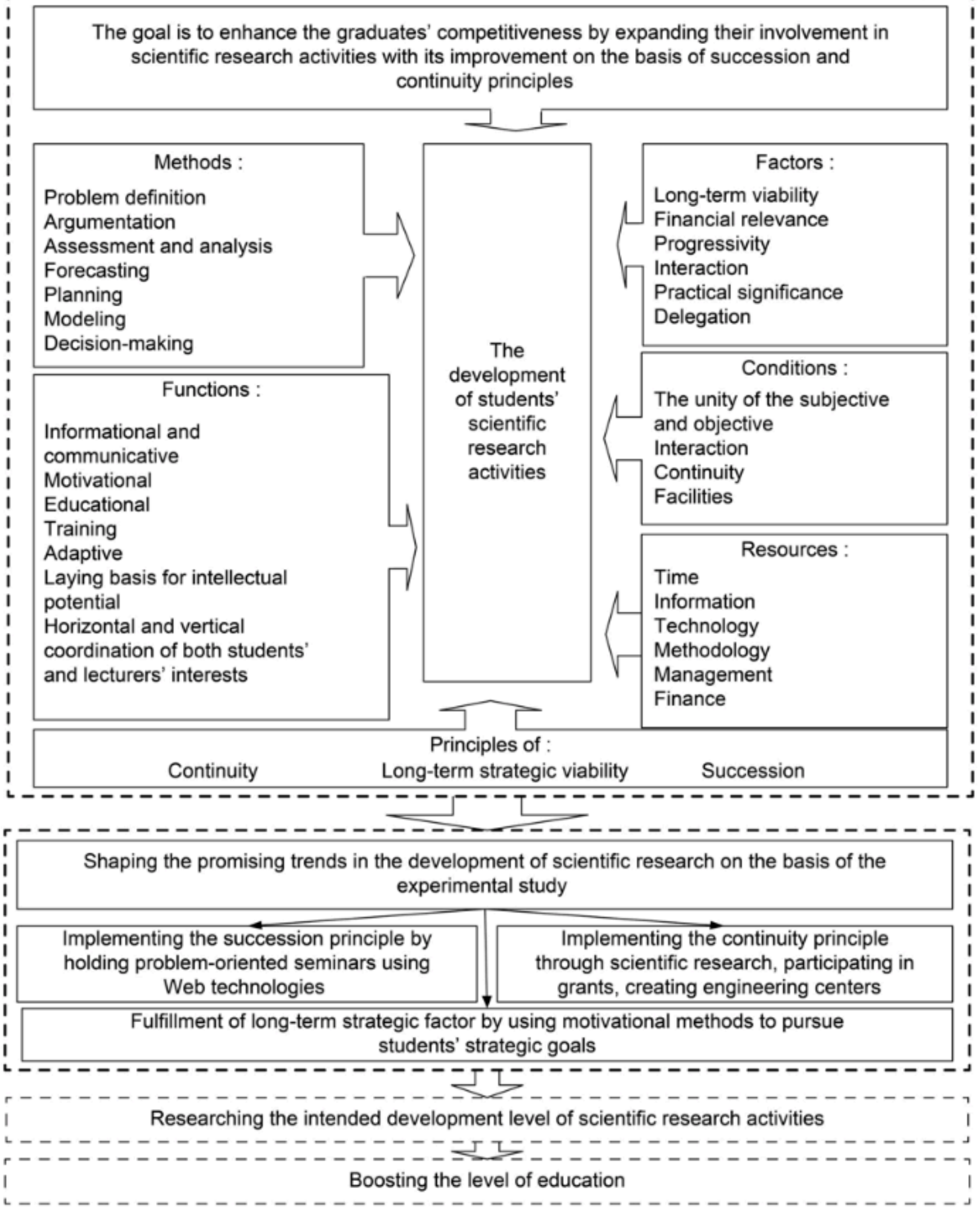
The analysis of the results of the second subgroup showed the predominance of the progressivity factor (56%) as well as the possibility of obtaining financial remuneration

(32%). Among the tactical factors, the respondents identified the interaction factor (62%) as well as the delegation factor (34%). Thus, the progressivity factor seemed to be the most significant. This reflects the students' interest in their own development in the process of research activities. The interaction factor is also decisive, reflecting the importance of succession in the process of scientific knowledge. The same is true for the delegation factor, which allows one to feel the importance of participating in and contributing to the continuous interaction with other students and supervisors.

The results of the study allowed us to develop a three-dimensional model of the development of the research activities of Russian students. The model comprises the following vectors: the implementation of the principle of succession, introduction of the principle of continuity, and execution of the strategic long-term viability factor

This model is based on the results of the sociological survey. Three key aspects of prospective reform of the educational process were identified for the further development of students' research activities. Unlike existing models, this three-dimensional vector projection levels the importance of ordinary factors and principles for the development of research, allowing the projection to reflect the continuous interaction of key vectors. The top of the vectors of the perspective development are represented by key principles and the most influential factors on the development of research activities. This was taken into account to develop practical recommendations for improving the theoretical and methodological decomposition model (Figure 6).

Figure 6
Decomposition Model of Theoretical and Methodological Tools for the Development of Research Activities of University Students Based on the Priority of the Principles of Succession and Continuity.



5. Discussion

Was found that both external and internal factors influence students' research activities. Students who have a more active research role tend to be affected mainly by tactical factors. It was found that the interaction factor played a main role (49% and 62%), which reflects the importance of succession in the students' scientific knowledge, as well as the factor of delegation (23% and 34%), which allows students to feel important in the process of the continuous interaction with other students and their supervisor. The survey was conducted in the academic year 2017–2018 and demonstrated, in contrast to the results of previous studies, that material content is less important than the interaction

between educators and students. This is an innovative direction for the creation of favorable pedagogical conditions for the students' full involvement in research activities. The results answered the research question by demonstrating that the key factors have a direct connection with continuity and succession. This also highlighted that the main characteristic of continuity is determined by the influence of each previous stage of education on the content of education, which is the characteristic of the next educational stage (Legenchuk, 2009). This characteristic contributes to the implementation of advanced education, as well as the prospect of preparing students for the development of new theoretical and practical knowledge.

Theoretical and methodological tools were modeled, considering it appropriate to present this in the form of systematized tools, to achieve a key objective to reasonably define methods and skills with respect to the formalization of tactical objectives. Also, an action program, with tasks, specific key impact factors, making operational/strategic decisions, all this to model a prospective outcome and control its achievement.

From these results, the introduction of a system of innovative pedagogical methods is recommended to obtain the necessary pedagogical conditions for updating the principles of continuity and succession in the development of students' scientific research activities. First, the succession principle has to be promoted. This can be done by: (a) conducting problem-modeling workshops with the active and equal participation of students and lecturers to improve the skills related to identifying problems and modeling the situation according to the personal experience of each participant; and (b) using Web-based technologies that allow the management of the educational and research process and the assessment of the comprehension process.

Second, the continuity principle has to be promoted through: (a) the active participation of students in project and grant activities (a successful example is the experience of students at G.I. Nosov Magnitogorsk State Technical University, who participated in the submission of eight applications in 2018 for the grant competition PAO "MMK"; and (b) the creation of engineering centers for the continuous exchange of accumulated knowledge and competencies.

6. Conclusions

This study demonstrated that students who engaged in research and development activities are largely influenced by tactical factors that, unlike strategic ones, demonstrate results in the short term. Among the factors influencing students' involvement in research activities are those factors that reflect the quality of the relationship between the students and the scientific and pedagogical staff of universities, represented by scientific supervisors. In addition, the possibility of interacting productively with other students is also important, as it allows students to demonstrate their accumulated intellectual potential to their peers. By identifying these factors, the principles for the development of research activities necessary for ensuring favorable pedagogical conditions, namely continuity and succession, can be developed. This model also developed a vector model, which was based on the most productive factors and principles in the development of students' scientific research activities. It includes three innovative components: strategic prospects, continuity, and succession. Such an approach will ensure the actualization of students' personal incentives for scientific research, which will form the competitive scientific and professional potential for university graduates.

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