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## **Organizational and Pedagogical Conditions for the Development of Professional Competencies in the Technical Students' Individual Work through the Example of Studying the Discipline «Hydraulics and Fluid Mechanics»**

Elena E. Guseinova <sup>a,\*</sup>

<sup>a</sup> Ufa State Petroleum Technological University, Russian Federation

### **Abstract**

The urgency of the given problem is caused by the necessity to develop an innovative education system capable of producing highly qualified specialists with a wide range of social and professional activities and broad-based abilities ready for individual operating innovative activities.

The article is intended to searching for the ways of scientifically based organization of students' individual work which is one of the most up-to-date area of a pedagogical research (focus), contributing to the development of professional competencies and the optimization of higher technical education.

The leading method of the given problem research is the pedagogical experiment, which makes it possible to identify, theoretically substantiate and experimentally test the organizational and pedagogical conditions for the development of professional competencies in the students' individual work.

In this research students' individual work is considered as an important pedagogical subsystem of the educational process, built with regard to its essential characteristics on the competency based and learner-centered approaches; at the same time, organizational and pedagogical conditions are realized: subject-subject relations between the teacher and students are built up, the prolonged differential tasks are used in the educational process with their gradual complication from adaptive to developing and constructive in the process of studying the academic disciplines, the development of professional competencies is regularly monitored.

The scientific and methodological materials presented in the article, used in the practice of professional education, ensure the development of professional competencies in the individual work of technical university students and streamline the workflow of the institutions of higher professional education improving the quality of education.

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\* Corresponding author

E-mail addresses: [guseinova\\_elena@hotmail.com](mailto:guseinova_elena@hotmail.com) (E.L. Guseinova)

**Keywords:** individual work, professional competencies, competency-based approach, learner-centered approach, organizational and pedagogical conditions.

### 1. Introduction

Significant changes taking place in the society at the modern stage, moving from industrial to information-oriented society have demanded the improvement of Russia's educational system and higher technical education as well. In the context of the Bologna Process, the Russian system of higher education must be compliant with European standards for the training of a highly-competent specialist capable of continuous professional self-improvement, with competences that would enable him to use them actively in professional activities (Gazaliev et al., 2004; Berulava, Berulava, 2010; Shaidullina et al., 2017). In Russia, in vocational education competency-based approach began to be implemented through the development of students' competencies, developed on the basis of professional standards (Mikhaylichenko, Gromova, 2011).

In the light of the before-mentioned, from our point of view, the development of various types of individual work emerges full blown for higher technical universities.

The significance of individual work is greatly growing up due to the increase in the volume of scientific and practical information.

According to the opinion of many scientists, individual work forms at students the necessary volume and level of knowledge, skills and abilities for solving cognitive tasks at every step of training (Pidkasisty, Korotyayev, 1985), and develops mental set to systematic knowledge and skills acquisition. Individual work is one of the major conditions for student's self-organization in mastering the methods of professional activity.

In the context of the outlined problem, the implementation of the learner-centered approach seems to be productive for the organization of students' own activity, which improves the raising of professional development level.

The Russian Association of Engineering Education conducts public and professional accreditation of educational programs in Russian universities in engineering areas and occupations in accordance with international standards. The RAEE makes demands on graduates of engineering professions taking into account native and global trends. The basic requirements for professional competencies are reduced to the ability of graduates to deal with complex and innovative engineering challenges. Accreditation of educational programs contributes to the development of education and its further improvement.

Competencies are designed on the basis of the professional duties of the employee, but the understanding of competences which is put in the modern educational standards is not adapted. Such extremely generalized formulations of competencies leave considerable freedom for higher educational institutions in planning, organizing and measuring of learning outcomes. Freedom in determining learning needs or learning outcomes has required from higher school the solution of qualitatively new tasks in pedagogical activity.

### 2. Materials and Methods

Theoretical and empirical research methods were used: analysis of philosophical, pedagogical, psychological and methodical literature on the research problem; method of didactic modeling, discussion, questioning, questionnaire, testing of students, observation, generalization of pedagogical experience, pedagogical experiment, analysis and generalization of experimental data, methods of mathematical statistics. The methods of mathematical statistics include the statistical processing of data that was obtained during the experimental work. For the processing of the data obtained, the technique "Theory of Latent Variables" was applied, the criterion U of Mann Whitney was calculated and the angular transformation of Fisher were calculated. The choice of Mann Whitney's U criterion is based on the fact that the criterion is one of the most common and is used to assess the differences in severity for two unrelated samples, and the number of subjects in the samples may vary. The application of the criterion is most convenient in these cases when the samples are small in terms of the number of subjects (Ermolaev, 2003).

"The theory of latent variables", which is based on the Rasch model allows also to assess the quality of the measuring instrument. Every measuring tool had Chi-square that is greater than critical value at a significant level of 0.05 statistics, allowing you to use them as measuring tools.

The study measured locus of control. The definition of the control document was carried out according to the experimental-psychological method developed on the basis of the scale of the G. Rotter's locus of control in the Research Institute. Bekhterev and published by E.F. Bazhinym in co-authorship with E.A. Golyukoy and A.M. Erkind (Bazhin et al., 1984). The authors note the high reliability of the test. Validity is proved by the relationships of the questionnaire scales with other personality traits that were measured using the 16-PF Cattell's test.

Also according to the method, T.D. Dubovitskaya determined the level of motivation of students to learning. The methodology is characterized by a high degree of reliability and validity, calculated according to the formula of Rylon, the indicator was 0.933, and the value of the Student's criterion significantly exceeded the one-percent level of significance (Dubovitskaya, 2002).

A set of tasks was developed for assessing the operational-effective criterion in the discipline «Hydraulics and fluid mechanics» in branch of the University.

The trial facilities of the research was a Branch of Ufa State Petroleum Technological University in the City of Oktyabrsky, Republic of Bashkortostan. The study covered 265 students, activities among students in the second and third years, full-time, part-time and correspondence forms of training.

The study was conducted in three stages.

At the first stage the analysis of available sources in the domestic and foreign literature on the research problem was carried out; the experience of an individual work organizing in the institutions of higher education of the humanitarian and technical profile was studied; the study on up-to-date requirements to vocational training of technical university students was conducted; professional competencies were specified; the set of competencies was determined; a criterial-evaluation tooling for determining the development of professional competencies was revealed and justified; the organizational and pedagogical conditions were justified.

At the second stage, the formative experiment was carried out to verify the developed organizational and pedagogical conditions for the development of professional competencies.

The third stage of the study included testing, analysis and processing of experimental results; verifying of the effectiveness of the organizational and pedagogical conditions for the development of professional competencies in the individual work of students; generalization of the results obtained during the experiment; clarification of the research conclusions.

### **3. Discussion**

The problem of students' individual work organizing has emerged not at present days, it has been discussed by many educator thinkers for centuries. In the writings of Ancient Greek scientists – Socrates, Plato, Aristotle it is mentioned about the importance of individual acquirement of knowledge. In the pedagogical works of I.G. Pestalozzi, Ya.A. Comenius, J.-J. Rousseau ideas associated with the individual development of children are considered. In different years of the twentieth century, teachers appealed to understanding of individual work, in the 20s–30s they tried to determine the essence of this concept. In the 1930s and 1940s, individual work was considered from the point of view of the didactic-methodological approach. In the 60s–80s scientific and technical revolution put school to the task of forming conscious creative activity and independence in the perception of students. By the beginning of the 21st century information and computer technologies had a favorable effect on the organization of learning and cognitive activity. A whole generation of training resources has emerged that operate on the basis of computer technologies, in addition, they generate a higher return from education. This has required increase of the amount of students' individual work, and also it induced to look for the ways of improving the quality of individual work, which relates to the basic forms of the educational process organization.

The concept of "individual work" is revealed in the works of many researchers. Individual work is considered as an activity; includes the search for necessary information, the acquisition and use of knowledge; it is conducted by the student independently without direct participation of the teacher (Gomoyunov, 1988); acts as a system of organization of pedagogical conditions that ensure the management of learning activities in the absence of a teacher (Graf et al., 1981); supposes the performing of various tasks, which are a means of mastering knowledge and forming creative skills and abilities; supposes the creation of problematic situations in the form of cognitive tasks (Pidkasistiy, Korotyayev, 1985).

The competency-based approach at the present time of the society development, being an advanced model of education determines a set of competencies and competences representing the body of knowledge, skills, experience, work methods. The competency based model was reflected in pedagogical researches of many scientists.

There is a theory of language competence, which means "catholicity of linguistic knowledge of the native language" (Chomsky, 1965). Competencies can be filled with personal components, such as motivation; consist of a large number of relatively independent from each other components (Raven, 1984); cause difficulties in measuring and evaluating them as a learning outcome (Zimniaya, 2003); in education it can designate integrated characteristics of the training quality (Shadrikov, 2004).

Competence is regarded as: the quality of a person who has got education at a certain stage and is ready for productive activity, considering its social importance and social risks associated with it (Tatur, 2004); possession of certain skills, knowledge, life experience that allow you to judge something, do something, or decide something (Shadrikov, 2004); substantial generalizations of empirical and theoretical knowledge, presented in the form of principles, concepts, sense-making matters (Zeer, 2006); possession of the relevant competence by a person, which includes personal attitude to the subject of activity and competence (Khutorskoi, 2005); integrated characteristics of personal qualities, the training of a graduate, contributing to the conducting activities in certain areas, expressed in the readiness for carrying out any activity in specific professional situations. Competence is a total of cognitive, motivational, value-based and social components (Frolov, Makhotin, 2004).

Despite a significant amount of researches and developments in the area of a competence approach implementation in vocational education, only some works to the problem of professional competencies development for engineering specialities in technical universities are devoted. The possibilities of individual work in this area remain insufficiently investigated. One should note the inadequacy of the development of theoretical and methodological foundations that ensure large-scale implementation of a competency-based approach into engineering degree.

## **4. Results**

### **4.1. Theoretical basis of the development of students' professional competencies**

In our research, competence represents an ability to apply knowledge and skills for successful activities in a certain field, an ability to perform labor functions, the conformity of a professional with the requirements for a definite occupation.

The concept of "professional competence" can be presented as an opportunity to acquire new knowledge, skills, abilities, powers; the possibility of effective use of abilities in the course of professional activities; as well as integration in the field of expertise, knowledge and skills, the presence of personal qualities.

Based on the researches (Dyachenko, Kandybovich, 1976), the criterial structure of professional competencies development, consisting of cognitive, operational-effective, motivational-value and reflective-evaluative criterion was determined and proposed. The basis of the motivational-value criterion is the system of the student's motivational value-based attitude toward himself and his activity. He describes the student's need for research, cognitive activity, the need for self-expression in the process of cognition, decision-making and evaluation. The cognitive criterion is the system of knowledge that works towards development of students' scientific world views. This criterion forms methodological skills at students, allowing the student to organize individual cognitive activity. The operational-effective one is manifested in qualities necessary for comprehension of individual activity goal, creativity, as well as for the vision of the problem, the posing of questions, the hypothesis, the ability to structure the material. Reflective-evaluative criterion is a cognitive attitude of students to learning outcomes, an ability to evaluate results, mistakes of his own and other students' activity, an ability to self-regulation.

For the motivational-value criterion the level of interest to the developed profession is the developmental quotient. The level of lessons learned is the developmental quotient of the cognitive criterion, and the level of individual cognitive activity is the quotient of an operationally effective criterion. The reflective-evaluative criterion is characterized by the degree of adequate evaluation of the results of competence development. Each criterion is represented by three indicators: low, medium and high.

The development of professional competencies in the individual work in our research was actualized on the interrelation of the basic principles of system, competency based, learner-centred and activity-based approaches.

The learner-centred approach lays the groundwork for the formation of a student as an actor able to realize his life-sustaining activity and his personal essence in the educational process and in the future professional activity. The implementation of the learner-centred approach takes place in conditions of individual identification and awareness of the means and conditions of the students' activity, ensuring their subjective position in the teaching and educational process, building the relational system between the teacher and students on the basis of frankness, trust, dialogue. The effectiveness of the educational process depends on the involvement of students into active learning activity, as a person develops and presents himself in activity. By organizing the students' activity, the teacher develops students' social and professional work experience, functions and abilities.

The main conceptual situations of methodological approaches became the basis for the realization of organizational and pedagogical conditions: the creation of subject-to-subject relations, the use of differentiated prolonged tasks, and the monitoring of the educational process (Guseynova, 2015).

In our study, subject-subject relations represent the business relationships of equal partners in joint working, which are built on the basis of support, trust and cooperation. Students, being the subjects of learning and cognitive activity, should know how this activity is carried out, they should have the potential for searching and making independent creative decisions, for unveiling their creative abilities. Dialogue is one of the most effective ways of subject-subject interaction, reflecting the transition of pedagogical interaction to a personal level.

The effective formation of subject-subject relations is influenced by the subjective characteristics of teachers: an ability to build relationships based on the dialogue, the presence of professional and pedagogical knowledge and skills, the presence of personal qualities, the focus on mutual understanding and mutual trust.

The prolonged tasks in our study are represented by professional, differentiated tasks of a long-lasting nature, which are carried out in stages, on the basis of their gradual complication in the process of studying the student course. The students organize the order of task performance with their gradual complication in the process of studying the student course from adaptive to developing and creative.

The third pedagogical condition for the development of professional competencies is the monitoring of the educational process, which represents a regular and systematized procedure of the accumulation, storage, processing and dissemination of information about the educational system. Monitoring enables the educational process to be followed and corrected timely and it becomes directed.

#### **4.2. Experimental work on development of professional competencies of students in the individual work**

At the ascertaining stage of the experiment, factors and conditions that influence the development level of professional competencies were revealed.

There was defined a set of professional competencies in the discipline «Hydraulics and fluid mechanics», the development of which was supposed to be obtained at students.

In the discipline «Hydraulics and fluid mechanics» it is supposed to have lectures, practicals, lab practicals as well as the performance of homework calculation tasks. The organization of individual work is provided during all types of classes.

At the ascertaining stage of the experiment a questionnaire was conducted among intramural (173) and extramural (48) students for identifying the level of students' motivation to study at the university, which showed that the students have insufficient level of internal motivation for learning activity. The survey was conducted in eleven study groups of second and third year of the branch. In general, extramural students show a higher percentage of internal motivation.

At the ascertaining stage of the experiment, we conducted a survey to determine the formedness index of locus of (direction) control of students. The survey conducted among the third-year-students in the Branch of Ufa State Petroleum Technological University in the City of Oktyabrsky showed that all interviewed students have an average level of subject control development. This index corresponds to the fact that students can take responsibility, and they also can charge with other people, declining all responsibility for what is happening.

At the forming stage of the pedagogical experiment, a set of organizational and pedagogical conditions for the development of professional competencies was realized. In the early stages of the competence development process, according to the requirements of educational state standards, the most important professional competencies were determined. Then the forming experiment was arranged in the following order: pedagogical technologies directed to the competence development were used; an educational environment was formed in which students and teachers were equal subjects of the educational process; the educational process was monitored.

Students of the training program 131000 «Petroleum Engineering», an educational program specialization «Operation and Maintenance of Oil Production Facilities» took part in the experiment. At the premises of the testing site for conducting the experiment and for testing the hypothesis, two groups of students were formed: control and experimental. While creating samples, the strategy of attracting real groups of students was applied. The selected student groups were homogeneous in composition. The group BGR-11-11 took on the role of experimental group (23 students), and the group BGR-11-12 – of control one (21 students).

In the experimental and control groups of students, a testing was conducted aimed to identify the initial level of training, which did not reveal any significant differences in the training of students. The measurement was carried out within the framework of the "Theory of Latent Variables" on the basis of the Rush model.

The basis for the motivation and value criterion for the development of professional competencies is the motivation for learning activity, manifested in its interest. In the control and experimental groups of students there was conducted a questionnaire, aimed at identifying the direction and level of the internal motivation development of students' learning activities. In the control and experimental groups, a questionnaire was conducted using the Dubovitskaya technique, aimed at identifying the direction and level of development of the internal motivation of students' learning activities. At the initial stage of the experiment, a low level of motivation in the control group was observed in 19 % of students, the average in 57 %, and a high level of motivation showed 24 %. In the experimental group, a low level of motivation was noted in 22 % of respondents, an average in 65.2 %, a high level in 12.8 %.

At the next stage of professional competencies development in the students' individual work, it was supposed to organize the teacher's activity on the basis of previously selected educational technologies, approaches and methods.

We proposed to increase the effectiveness of the professional competencies development in the individual work of technical university students by the organization of pedagogical conditions promoting to maximum display of students' independence.

We used the following pedagogical methods, tools and organizational forms of training: the use of prolonged tasks and problems associated with specific workplace problems; the mainstreaming used during lecture reading (keeping the log-books); the students' research work during the preparation of reports for conferences; individual work in small groups during lab practicals.

In the implementation of first organizational and pedagogical condition – the creation of subject-subject relations between the teacher and students – we cultivated sincerity and authenticity in communication, finick, benevolence, tact and pointed to the creation of equal relations. The development of students' subjective position was facilitated by their involvement in various activities, the enabling of free choice capability of educational activity elements. In the course of experimental work, to the development of students' abilities to put up the goals of the forthcoming activity was paid much attention as well as to the independent achievement of their objectives. In the course of the experiment, the teacher is keen to develop at students the communicative and reflexive skills. The students were given the opportunity to ask, perceive, comprehend the necessary information, also they gained reasoning experience, arguing experience and the experience for defending their point of view. The dialogic communication promotes more conscious creative acquisition of the material, provides a supportive environment in the classroom, develops equitable and open relations.

The usage of point rating system at students promotes the increasing of motivational level, allowing to monitor the quality of the knowledge and skills acquisition by the students, in particular inducing the latter to performing the tasks properly, to reducing timely performance, to the pursuance of creativity. For its successful implementation the individual schedule of individual work was drawn up, in which different types of work, the meeting deadline and the points given for

it were reflected. The problem of motivation was solved during the performance of the tasks, the doing of which gave the opportunity for students to see the results of their activities clearly. Also, pedagogical impact with motivation and encouragement contributed to the increase of the motivational level. In the course of the work, the teacher gave additional points to the students for displaying an active attitude on their own initiative and for perfect performance of the tasks. Charitable conditions were created for less advanced students, additional time for pondering a solution of the tasks was given. At the same time, a system of penalty points was used for the late performance of the tasks and for substandard quality of performance. Some students received additional tasks. Personal individualization of the tasks was widely encouraged.

In the course of the formative experiment we managed to discover new aspects of individual work conducting at the lectures. The originality of our approach during this part of the experimental work consisted of that we had changed the role functions of the subjects of the educational process.

During the lectures, the students of the control group had the opportunity to prove themselves as lecturers, that promoted the formation of search skills and information processing skills, the mastering of new interaction technologies between the group and information delivery methods with the developing public speech and listening skills, the communicative culture of students was developed.

The application of the «Log-book» strategy makes possible to have the dialogue between the lecturer and students. The students were given the opportunity to work out the learning material during the lecture in an active form.

The use of the individual work in small groups during the lab practicals contributed to the creation of conditions for self-development and self-realization, to the formation of cooperative relationship while searching for ultimate solution to the problem.

The realization of the second pedagogical condition which is the use of the prolonged tasks took place during the practicals. In our research, developing variative types of differential prolonged tasks for individual work, providing for the gradual complication of tasks, we looked out of the following types of tasks: adaptive, developing and creative. The students chose the appropriate level of tasks themselves. The individual work was conducted during the in-class learning. The students received bonus points for their active work.

The third pedagogical condition for the development of professional competencies in the students' individual work is the monitoring of the learning process. Monitoring promotes the development of the addiction to systematic task performing. We conducted a current and a final control. «The schedule for students' individual work» was developed in the discipline, which reflects the main "working points" of the discipline, according to which the points are scored within the frame of the point rating system. Additional monitoring was conducted during lectures, practicals and lab practicals.

The comprehensive realization of the organizational and pedagogical conditions for the development of professional competencies in the students' individual work made it possible to conclude that the technical university has the potential for the training of specialists capable of functioning in the constantly developing professional environment.

During the formative experiment, the students were able to develop communicative skills while working in small groups in practicals and laboratory practicals, creative skills in choosing the ways of performing the work, the skills to acquire knowledge independently, to use the basic laws of science disciplines in professional activities, to plan and conduct experimental activities.

At the final stage of the formative experiment on the professional competencies development in the students' individual work, analytical, corrective actions of pedagogical activities were carried out. A comparative analysis of the results obtained in the experimental and control groups of students was carried out based on the criterial apparatus for the development of professional competencies developed initially.

**Table 1** presents comparative analysis of the level of cognitive criteria development in the control and experimental groups of students' preparedness during the semester.

**Table 1.** A comparative analysis of the level of students' preparedness

Group	Time	Average value	Standard error	Low level	High level
BGR-11-11	1	1,786	0,201	1,387	2,185
	2	2,443	0,201	2,044	2,842
BGR-11-12	1	1,561	0,210	1,144	1,979
	2	1,694	0,210	1,267	2,122

Table 2 presents the criteria for development of professional competencies in the control and experimental groups at the end of the experimental work.

**Table 2.** Levels of professional competencies development at the end of experimental work

Groups	Components	Levels of professional competencies development					
		Low		Average		High	
		man	%	man	%	man	%
EG	Cognitive	1	4,3	5	21,7	17	74
	Motivational value	2	8,7	13	56,5	8	34,8
	Operational-effective	1	4,3	9	39,2	13	56,5
	Reflective-evaluative	1	4,3	13	56,5	9	39,2
	Professional competencies	1	4,3	10	43,5	11	52,2
KG	Cognitive	5	23,8	8	38,1	8	38,1
	Motivational value	2	9,5	15	71,4	4	19,1
	Operational-effective	4	19,1	11	52,4	6	28,5
	Reflective-evaluative	3	14,3	13	61,9	5	23,8
	Professional competencies	3	14,3	12	57,1	6	28,5

A comparison of the results of the implementation of organizational and pedagogical conditions showed that the experimental group had experienced a greater increase in the level of professional competencies development. In the experimental group, the number of undeveloped students decreased by 13.1 %, and the group with a high level increased by 30.5 %. In the control group, these figures are lower, a decrease by 4.7 %, and an increase by 4.5 %.

To assess the effectiveness of the experimental impact, statistical processing was carried out on the basis of nonparametric methods. Based on the results of the calculation of Mann-Whitney U, a conclusion was made about the criterion for the reliability of the difference between groups ( $p \leq 0.05$ ), which was subsequently confirmed by calculation of  $\varphi^*$ -the criterion of the Fisher angular transformation. Critical values of  $\varphi^*$  were obtained for two levels of statistical significance 1.64 ( $p \leq 0.05$ ) and 2.31 ( $p \leq 0.01$ ). The calculated empirical values  $\varphi^*$  for the transition from a low level of development of professional competencies to the average level (3.062) and at the transition from the middle level to the high level (2.509) are greater than the critical values, which was confirmed by the effect studied.

The value of Chi-square  $\chi^2$  calculated for each component of professional competence in the experimental and control groups, with statistical significance level  $p \leq 0.05$  was higher than the critical value. For cognitive and operationally-effective criteria obtained value of  $\chi^2$  was higher than the critical values at the significance level  $p \leq 0.01$ . The obtained results also confirmed the investigated effect.

## 5. Conclusion

The experimental work on the development of professional competencies has made an impact on the effectiveness of the formation of a competent specialist ready to work in a professional environment.

The information of the article can be recommended to teachers of higher and secondary educational institutions to ensure the development of professional competencies in the individual work of students and to optimize the work of higher vocational training institutions for improving the quality of education.

The study does not pretend to have exhaustive results on this subject and can be continued.

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