Developing Individuals' Professional Qualities in the course of Technosphere Safety Specialists Training

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Abstract. The article focuses on the methodology for assessing the development of professional qualities of future specialists majoring in Technosphere Safety. Due to the globalization of production, the Russian education system is being integrated into the world educational network. At that, the range of qualifications required from a specialist of any field is expanding. These processes are changing the paradigm of professional education. The goal of professional training is not merely the total sum of necessary knowledge, but – above all – the development of professional qualities. The existing grading system needs to be introduced with an integrated set of grading methods that should take into account the achievement in natural science subjects, the intellectual development, the expert assessment, and professional communication skills. Educational monitoring of developing professional qualities must be carried out at every stage of teaching. In that way, a graduate, a soon-to-be specialist in the field of Technosphere Safety will not be a mere operator, but a holder of advanced engineering knowledge.

Introduction

Current integration of Russian education system into the global education network presupposes introduction of additional international professional requirements into the state educational standard of professional training. Thus, Washington Accord (WA) and European Network for Accreditation of Engineering Education (ENAEE) described general requirements to the competencies of engineering graduates taking into consideration particularities of national education systems, including the following: knowledge of engineering subjects (application of knowledge of mathematics, natural philosophy and applied science, along with specialization knowledge for conceptualization of engineering models); analyses of engineering tasks (identification, formulation, studying and solving complex engineering tasks to achieve necessary results using mathematical and engineering science), design and development of engineering solutions (designing solutions of complex engineering tasks, developing systems, components or processes to meet specific requirements with consideration for cultural, social and ecological aspects of health and environment safety); research (carrying out research for complex engineering tasks, including performance of an experiment, analyses and interpretation of acquired data, synthesis of information required to achieve the necessary results); use of modern set of tools (creating, selecting and applying corresponding technology, resources and engineering practices, including forecasting and simulation, to perform engineering in a resource-constrained environment); individual and team work (efficient operation both as an individual specialist and as a member or a leader of a team, inter alia a multidisciplinary one); communication (effective communication with a professional team and with the community in general in the process of performing engineering work, writing reports, completing paperwork, presenting materials, giving and receiving clear articulate instructions); engineer and community (understanding social and cultural aspects, issues in the field of health and environment safety, consideration of legal restrictions and liabilities associated with performance of engineering work); ethics (adherence to professional code of conduct and responsibility, as well as following best engineering practices); environment and sustainability (understanding the consequences of engineering solutions in the social context and showing knowledge to solve the challenges of sustainability); project management and finance (knowledge of management and business practices, including change and risk management, understanding the associated restrictions); lifelong learning (understanding the necessity of and having the ability to be a lifelong learner) [1, 2]. Therefore, engineering competence is a complex system of scientific and professional knowledge and skills, personal and professional abilities, which has to meet international standards of professionalism. The work of a Technosphere Safety specialist operating in emergency situations is universal in nature since it is involved in development of any technical equipment. On one hand, a professional has to work out the most effective operating conditions of the equipment, but on the other hand, they should minimize the harmful impact

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of technical process on health and environment as well as contain and mitigate man-made disasters. The range of professional competencies in the field has to be wide and diverse.

The rationale, the scientific significance and brief overview of the background

In our opinion, it is the methods for professional competency development, not changes in goals, contents or scope of disciplines, that are to become the basis for optimization of the educational process for the program of Technosphere safety. An optimal system shapes and develops student's thinking capacity and ability to base conclusions upon the system of logical and psychological knowledge on the structure of cognitive process [3]. An important step in training of a Technosphere Safety specialist is the organization of pedagogical monitoring of individual's professional competence development throughout all the period of education. The qualitative indicator of a junior specialist's professional readiness is the ability to solve engineering problems. Therefore, it is necessary to determine the means of assessment, i.e. criteria for evaluating individual's professional competencies, inter alia, the ability to solve engineering problems, i.e. to think technically[4].

The pedagogical science defines criteria as requirements a subject or an object have to meet. While developing the criteria, it is important to take notice of the following:

1) necessity to determine the criteria's area of application, their designated use;

2) semantic distinctness – precise definition of each criterion's meaning and unambiguousness of understanding of the criterion by all experts;

3) constructivity – features must be constructively described.

For instance, the following criteria are used to evaluate the level of future technology teacher's technical thinking development through knowledge and skills:

1) having the necessary technical and technological knowledge and skills.

2) mastery of technical and technological knowledge and skills.

3) mastery of professional pedagogical knowledge [5].

There is a different approach to determine the technical thinking development level. Thus, E F Kovalenko uses a multifaceted approach to assess the level of technical thinking: Bennett's test, Eysenck's Personality Test (subtest 4 and 5), Logical-Quantitative Relation test, Raven's Progressive Matrices.

Methods used by these authors are able to determine, in objective and true-to-fact manner, the level of technical thinking development during professional education, but they are not fit to evaluate the professional competencies of graduates majoring in Technosphere Safety

Statement of the problem

Therefore, it is necessary to work out methods and criteria to assess the level of technical thinking of Technosphere Safety students. Any measurement is carried out by comparing it to a given standard scale. However, the professional quality concerned is a combination of newly-formed personal skills which are shaped and developed non-simultaneously. That is why, in order to gain objective assessment, we formulated qualitative and quantitative criteria considering the integrative nature of the technical thinking of a future specialist, alongside with the procedural side of the measurement. The assessment process is prone to be influenced by multiple factors, so the end result might be different from true. In the course of our research, we have elicited all the external effects causing the errors to occur and determined the tolerance interval when assessing the level of students' technical thinking development.

METHODS

We define the goal of the assessment process as formulating the estimation of the object under study, i.e. technical thinking, the qualitative characteristic of which has gained a measured value. The assessment process is performed step-by-step at each educational stage:

1. Assessment of characteristic components of technical thinking is carried out.

2. Decision, conclusions and judgment are formed based on the assessment results.

The existing level of students' technical thinking development manifests itself in the process of its designated use while performing corresponding tasks and assignments. The assessment process is deemed objective when the assessed students show their professional quality in the most effective way. Thereat, a future engineering specialist has to undergo tests in which their technical thinking ability can manifest.

The professional quality of a student to be formed is defined as an objective sum of their personality's psychological traits. Therefore, a list of criteria to measure engineer's professionalism and qualifying requirements is determined by the system deemed which is to benefit from the successful end result. The outcome of tests, personal interviews and questionnaires allows us to make judgment on how well the technical thinking and the professional qualities of the students have developed.

Practical relevance, implementation suggestions and results, experimental findings

The assessment process of formation and development of students' technical thinking is an integrative complex of assessment methods that includes the following:

1. Students' academic record on the natural science subjects (current and final grades at every educational stage).

2. Students' rating as an indicator of their engagement in academic and research activities, expert assessment (seminars, conferences, rationalization work and inventive accomplishments).

3. Students' level of professional communicational skills according to professors' feedback and based on results of public presentations given during classes, seminars and conferences.

In the course of the research, we developed an evaluation scheme: whether the presenter stated the topic, the goal and the conclusions of the report, whether personal opinion on the topic was expressed or not, whether the conclusions were backed up with reasoning, whether illustrative, technical or display means were used or not, the way the blackboard was used (was it justified or not), whether the answers to the questions set forth were substantiated with reason, the overall impression the presenter created (articulate speech, calm and well-paced, confident performance, used no notes while giving the speech), recommendations to the presenter (aspects to work on).

4. Comprehensive assessment of a future Technosphere Safety specialist's personal qualities involves:

1) assessment of an individual's intellectual potential:

- acuteness assessment (method 2),
- self-assessment of intelligence (method 1),
- intelligence structure assessment (R. Amthauer's Intelligence Structure Test).

2) assessment of technical thinking, drawing interpretation skills, understanding equipment diagrams and the principles of their operation, solving physics and technical problems (Bennett's test).

The measurement tests should be:

- preliminary – based on the results, educational process should be planned,
- intermediary (adjusting) – the results of which allow to introduce necessary changes into the educational process;
- final tests – results of which give information on quality of educational activities, and their comparison to the results of prognostic tests will give the opportunity to adjust pedagogical leverage to form and develop technical thinking of future specialists majoring in Technosphere Safety.

Therefore, diagnostics of formation and development of professional qualities in the process of education is comprised of the following stages that are to be performed independently:

1. Diagnostics of academic record on the natural science subjects.
2. Research work rating (expert assessment).
3. Diagnostics of professional communication skills (expert assessment).
4. Expert assessment of students' personal qualities.

An important indicator is feedback on the quality of graduates' professional performance. The feedback should include: communication ethics – professional communication, knowledge of cutting-edge technology, responsibility and promptness, occupational mobility, professional image to match the set of job responsibilities. The collected feedback is the qualitative characteristics of graduates' professional success and it offers a means to improve the multi-layered system of engineering education[6].

Therefore, the integrated set of methods to assess the level of successive shaping and development of competencies is presented in table 1.

The results of diagnostics carried out in such manner allow for assessing not only the level of technical thinking development, but also individual's professional qualities.

Results

To prove the veracity of the presented criteria to assess competencies in the educational process in 2007–2016 in Peter the Great Saint Petersburg Polytechnic University, pedagogical monitoring was carried out in Higher School of Technosphere Safety[7]. In that way, the selection of control and experiment groups went naturally, it was made up of the student groups already formed and existing at the moment of the experiment. Considering that all measurements of any value

Table 1. Process stages of students' technical thinking assessment.

Assessment stage	Purpose
1. Qualitative analyses of solving and presenting of a typical test on a natural science subject Academic record on natural science subjects	Assessment of the basic level of technical thinking on the first educational stage (first year of learning).
2. Assessment of the overall intellectual development: - acuteness assessment, - self-assessment of intelligence, - intelligence structure assessment. - Bennett's psychological test	Students' academic record on the following educational stages is an additional criterion to assess the level of technical thinking.
3. Expert assessment of research work rating	Assessment of the student's intellectual development These methods are better suited for use in the second and third year of learning.
4. Professional communication	Assessment of individual's technical thinking, including their ability to interpret drawings and diagrams and solve physics and technical problems.
5. Feedback on professional performance	Assessment and analyses of combinatorial thinking capacity, ability to think beyond and understand relations.

populations are subject to the normal distribution law, the values close to the mean, as a rule, show main properties of the whole population, i.e. they are the most representative. To carry out the testing, we drew up tests on natural science subjects. Selection of control and experiment groups out of the population sample was performed with the method of cluster survey, which meant selecting two first-year student groups with non-sampling error.

The acquired data allow us to conclude that in experimental groups the number of students having the necessary level of technical thinking and competencies prevails over control groups.

Discussion

The findings obtained over all period of experimental work give the opportunity to describe generalized image of a future Technosphere safety specialist.

A student:

- in experimental group: has basic knowledge of natural science and vocational subjects; has clear understanding of scientific and engineering landscape; has self-management skills; is able to shape their own educational route (self-development); has experience of teamwork both as a subordinate and a leader; has professional communication skills, i.e. has a system of personal qualities that manifest themselves in the course of different socio-cultural and vocational interactions, at that the graduate exhibits said skills both in professional and general sense;
- in control group: has knowledge about the environment, society and up-to-date production technologies; is able to apply their knowledge and skills in order to gain new knowledge; has reflection skills. Graduates of control groups only exhibit technical thinking in general sense, they have developed the expertise to create new technology and modify the existing technology, to structure information needed to organize collective work of a man-machine system (AI); they have professional communication skills and know how to maintain ongoing self-development. They are good operators, but this is not enough for modern-day job market.

Conclusions

To sum up, the assessment of developed expertise level enabling undergraduates to solve professional and technical problems is carried out through pedagogical monitoring. The latter is based on the set of psychological and pedagogical criteria and grading methods. The measurement foundation includes:

- integral characteristic,
- assessment of individual's abilities influencing the professional becoming of an engineer,
- succession assessment of engineering training process in the framework of multi-layered educational system.

Practical implementation of presupposed pedagogical monitoring to the existing system of engineering education will allow for ongoing learning of a specialist, which is a continuous process[8]. It is realized through one's own educational trajectory and takes into consideration the changes in scientific and production fields, as well as psychological, educational and professional characteristics of an individual. The system we have developed is organically implemented in different forms in the frameworks of various independent educational institutions that are guided by one goal only – formation of important professional qualities of an individual.

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