Pedagogical Monitoring of the Professional Image Formation among Technosphere Safety Students

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Abstract. This article describes the experience of organising pedagogical monitoring over students majoring in Technosphere Safety at Peter the Great St. Petersburg Polytechnic University. Here are presented the methods of organisation, the gained results, and the practical applicability of the latter. The pedagogical monitoring was carried out over the course of seven years, having the students and the teaching staff of the Technosphere Safety high school involved. The goal of the monitoring was to examine the formation dynamics of students' professional image. The professional image taking into account the standards set forward by the potential employers ensures the future specialists will meet world-class standards and be highly-employable at the Russian labour market. The article offers recommendations on forming the professional image of a Technosphere Safety specialist in the educational process, considering the role of employers' community.

1. Introduction

At the global educational arena, the performance of universities is assessed via various ratings, e.g. institutional rating, TOP-200 Engineering & Technology, TOP-400 Natural Sciences, subject rating: TOP-200 Civil & Structural Engineering; TOP-300 Mechanical, Aeronautical Engineering and Physics & Astronomy; TOP-400 Computer Science & Information Systems, Electrical & Electronic, Material Science, TOP-500 Economics & Econometrics и Mathematics, Times Higher Education, Round University Ranking. These ratings involve assessment of the university on the following positions: academic reputation, teacher/student ratio, citation index, internationalisation level, reputation at the employers' community. However, the share of the latter indicator only accounts for 10% of the rating. In the pursuit of high scores, the professional component of training is overlooked, i.e. the interaction of the future specialist with the employers and the formation of the professional image. This trend can be witnessed both in domestic and global educational systems. Here are the research results of the Professional Engineers Education Foundation. The research involved eleven electrotechnical and machine-building programs, six colleges and universities in the USA, which represent a sample of American bachelor's programs in engineering. It has been discovered that the modern system of training technical specialists focuses primarily on gaining the technical knowledge followed by remote preparation for professional practice. At engineering and technical courses, the
tradition of putting theory on pedestal prevails, ultimately diminishing the significance of engineering practice. It is necessary to pay due attention to the professional operations of the future specialists and to form the needed professional competencies along with the professional image since the very first years of training for the bachelor degree in engineering. This is particularly important for the specialists in Technosphere Safety, as their actual work is done under hazardous conditions. The graduate has to be prepared for working in any kind of situation, needs to be able to assess the technical level of new promising engineering models at the their development stage in contemporary engineering practice [1,2,3].

2. Statement of the problem
The roles of theoretical knowledge and professional operations must be equalised in the system of bachelor's degree programs in engineering. Not only is it crucial to teach professional competencies to the engineering graduates at the final stages of the education, but also to establish the conception of what a specialist must and can do, as well as what competencies to possess, i.e. to form a professional image. The professional image of the graduate includes:

- motivation for the professional activity,
- professional competencies,
- a contemporary understanding of the global engineering landscape,
- strive for self-education.

The development of modern technologies is changing not only the character of engineering activity, but the contents of professional competencies, i.e. the professional image. However, it must always correspond to the demands of its time. The engineering bachelor's degree programs must form not just the professional competencies, but the professional image of the graduate as whole, which accounts for the contemporary requirements of the employers’ community and has a proactive nature. To provide flexible response to the professional demands, it is essential that pedagogical monitoring of the professional image is developed and implemented into educational process. Pedagogical monitoring is defined as a comprehensive set of measures to assess the student's activity throughout all of the educational period according to the following indicators. [5,6]

2.1. Assessment of the engineering thinking:
Timeliness of the engineering thinking (basic and professional components) is the time spent on forming an illustrative image based on a technical concept or apparatus.

Flexibility of the engineering thinking is the ratio between basic and professional components, i.e. the ability to transfer concepts and images from one scientific area to another (the knowledge of physics onto chemistry, etc.).

Orientation of the engineering thinking means prevalence of one component over another, i.e. the factor which equals to the ratio of basic component to professional. If the factor is less than one, it is necessary to bring focus to the professional aspect of the studies. [7]

2.2. Assessment of the professional competencies of students in the system of bachelor's degree programs in engineering:
Intellectual culture

Technical abilities

Professional competencies

Assessment of the contemporary understanding of the global engineering landscape

Achievement in natural sciences and professional disciplines.

Pedagogical monitoring based on the proposed criteria needs to be performed by joint efforts of the teaching staff at all courses throughout all of the educational period of students.
3. Practical part

As part of studying the professional image, a comprehensive assessment program has been developed alongside with pedagogical monitoring being performed.

The program included the following properties and methods of their assessment:

1. The timeliness of engineering thinking was assessed per the time spent to complete the task. For this purpose, there were created attesting assessment materials such as control tasks and tests intended to be done in a strictly defined time.

2. To assess the flexibility of engineering thinking, the following materials were used: test achievement evaluation, modified Gilbert test, and Self-assessment of the Testee questionnaire.

3. The orientation of engineering thinking was assessed according to the results of tests consisting of two parts (basic and professional).

4. Assessment of general intellectual development was based on Acumen Evaluation, Self-assessment of Intellect, and Evaluation of Intellect Structure tests.

5. Assessment of students' technical abilities was carried out using Technical Abilities Assessment test (subtest 1, 2, 3).

6. Professional competencies were assessed based on:
   - expert evaluation of professional communication of the examinees (performance at conferences and seminars),
   - learning and scientific activities rating,
   - 'Self-assessment' questionnaires,
   - feedbacks on learning and scientific activity,
   - graduates' professional achievement reported from the employers' community.

Pedagogical monitoring at Peter the Great St. Petersburg Polytechnic University was carried out from 2010 to 2020, more than 300 Technosphere Safety students took part in it. The following tasks have been solved during the monitoring:

1. Criteria were established for:
   - the level of engineering thinking through indicators: timeliness, flexibility, orientation;
   - individual's abilities influencing the development of technical thinking via the following indicators: intellectual culture, technical ability, professional competency.

2. Methodology of statistical data analysis (Student's method) and algorithms to evaluate indicators of engineering thinking level were perfected, unit weight of tasks in attesting assessment materials was determined, experts were established.

3. A comprehensive program for formation and diagnostics of professional image has been developed.

Pedagogical monitoring was based on a complex approach including the following stages of the experiment:

- establishing – testing experimental and control groups formed to complete the experimental tasks (attesting assessment materials) to elicit indicators defining the level of engineering thinking of students in multilevel educational process;
- forming – practical implementation of the program to educational facilities;
- controlling – checking the results of the forming experiment.

The first educational stage of the establishing experiment involved developing and trying out the pedagogical monitoring, devising its process chart, determining the pool of participants.

The main hypothesis of the experiment was presented in the frame of verification of statistical hypothesis:

H₀ - presence of professional image.
H₁ - absence of professional image.

Student's t-test was chosen as a statistic criterion of hypothesis cohesion.
\[ |j| = \frac{|\Delta_j|}{\sqrt{\frac{1}{m} (|\Delta_1| + |\Delta_2| + \ldots + |\Delta_m|)^2}} \], where \( \Delta_j = \xi_j - \bar{\xi}_j \)

The study applied the level of statistical significance as \( \alpha = 0.05 \), which allowed to ensure the confidence coefficient of the gained outcome as \( \rho = 0.95 \).

Based on the figures, the numerical value of the hypothesis acceptance criterion was set at \( t = 2.056 \).

Thereafter, the deciding rule for all the face values can be reduced to the following expression:

\[
\begin{cases}
H_0 \div t \geq 2.056 \\
H_1 \div t \leq 2.056
\end{cases}
\]

Hypothesis was put forward that the proposed methodology of organising pedagogical monitoring of the Technosphere Safety students' professional image makes it possible to assess the formation of students' professional image. The aforementioned hypothesis was confirmed by the acquired results presented in the tables and diagrams. The outcome showcases the effectiveness of the suggested organisational and psycho-pedagogical conditions – a comprehensive program.

4. Conclusion
The results of organising the pedagogical monitoring have demonstrated that the professional image serves as the indicator of the Technosphere Safety graduate's preparedness to perform their professional duties and meets all the requirements of the employers' community. All this has become a basis to develop and introduce the pedagogical concept of forming the professional image in educational process of the bachelor's degree programs in engineering. In the course of theoretical analysis, the concept of professional image was defined to include the following:

1) engineering thinking is an integral characteristic consisting of basic and professional components. It is formed and developed while an individual is engaged in a transforming activity, e.g. learning and professional, it is characterised by motivation and readiness to perform professional activity;

2) professional image is formed at different educational stages, in the course of various types of students' activities (learning, scientific and professional), therefore, the provided pedagogical and psychological conditions need to be successive;

3) forming the professional image has to correspond to the contemporary requirements at each time interval and has to be accompanied by pedagogical monitoring;

4) implementing up-to-date didactic materials, testing and training programs is essential, it consequently leads to innovation of the educational process, which, in turn, will have an auspicious effect on the system of engineering specialists' training as a whole.

Therefore, the professional image of a Technosphere Safety specialist includes main values of the education contents – professional competency; adequate orientation in a difficult situation; sensible decision-making; adoption of scientific way of thinking, ability to transfer knowledge onto new areas, etc.

5. References
[1] Leonova N, Avdeeva M, Kaverzneva T 2019 Developing Individuals’ Professional Qualities in the course of Technosphere Safety Specialists Training E3S Web of Conferences EECE-2019 Vol. 140 08008 DOI: https://doi.org/10.1051/e3sconf/201914008008

[2] Skrypnik I L, Ksenofontov Yu G, Kaverzneva T T, Rumyantseva N V, Kiss V V 2020 Assessment of technical level of new, promising models of equipment at the stage of their development in modern engineering practice IOP Conference Series: Materials Science and Engineering Vol. 862(4) pp 042031(1-8) doi:10.1088/1757-899X/862/4/042031

[3] Leonova N A, Kaverzneva T T, Borisova M A, Skripnick I L 2018 Integration of Physics Courses and Operating Security Courses in the Education in the Technosphere Safety Area
Proceedings of 2018 17th Russian Scientific and Practical Conference on Planning and Teaching Engineering Staff for the Industrial and Economic Complex of the Region PTES 2018

[4] Kaverzneva T T, Rumyantseva N, Uljanov A, Belina N 2019 Use Of The Logical-Statistical Model As A Procedure For Assessing Occupational Risks In The Osh Management IOP Conference Series: Materials Science and Engineering Collection of materials of the International scientific-practical conference "Quality Management and Reliability of Technical Systems". Ministry of Science and Higher Education of the Russian Federation of Peter the Great St. Petersburg Polytechnic University C 012091

[5] Lawrence R and Heron C in 2016 IEEE Pulp, Pap. For. Ind. Conf. (IEEE, 2016) pp 174–181

[6] Rachev S, Dimitrov L, Karakoulidis K, Ivanov I D and Anghel Drugarin C V in 2018 Int. Conf. Appl. Theor. Electr. (IEEE, 2018) pp 1–6

[7] Ikonen E and Heikkinen P 2000 Neural Comput. Appl. 9 165

[8] Widodo P M and Rinaldy D 2019 J. Eng. Sci. Technol. 14 1055

[9] Chusov A, Podporkin G, Pinchuk M, Ivanov D, Murashov I, and Frolov V in 2016 33rd Int. Conf. Light. Prot. (IEEE) pp 1–9

[10] Murashov I, Frolov V, Ivanov D in 2016 IEEE NW Russ. Young Res. Electr. Electron. Eng. Conf. (IEEE) pp 625–628

[11] Shonin O B and Pronko V S 2016 Journal of mining institute 218 270

[12] Obraztsov N V, Subbotin D I, Popov V E, Frolov V Y, and Surov A V J. Phys. Conf. Ser. 1038 012137

[13] Churkin I S, Ivanov D, Frolov V, and Uhrlandt D 2011 in 19th Symp. Phys. Switch. Arc 2011, FSO

[14] Aleksandrov V I and Jerzy Sobota 2015 Journal of mining institute 213 9

[15] Tao R, Xiao R, and Liu W 2018 Proc. Inst. Mech. Eng. Part A J. Power Energy

[16] Sun H, Yuan S, Luo Y, and Guo Y 2016 Paiguan Jixie Gongcheng Xuebao Journal Drain. Irrig. Mach. Eng.

[17] Khechuev Y D, Kalashnikov B E Russ. Electr. Eng.

[18] Zagirnyak M 2019 Przegląd Elektrotechniczny 1 106

[19] Tahboub K A, Albakri M I, and Arafeh A M Vol. 4 ASME/IEEE Int. Conf. Mechatron. Embed. Syst. Appl. 19th Reliab. Stress Anal. Fail. Prev. Conf. (ASME, 2007) pp. 209–217

[20] L H de Paula, F C Storti, and E Fortaleza 2015 IFAC-PapersOnLine 48 33

[21] Makarov A and Kukhtik M in 2018 Int. Ural Conf. Green Energy (IEEE) pp 265–269

[22] Jiang Z B, Zhong T and Rao Y H in 2011 Int. Conf. Inf. Technol. Comput. Eng. Manag. Sci. (IEEE) pp 131–135

[23] Artyukhov I I, Bochkareva, Molot R V in 2014 Int. Conf. Actual Probl. Electron Devices Eng. (IEEE) pp 11–17