Formation and Analysis of Competencies in Elite Engineering Specialists

Oxana M. Zamyatina, Olga M. Solodovnikova, Darya S. Denchuk
Elite Engineering Education Department
Tomsk Polytechnic University
Tomsk, Russia
eto@tpu.ru

***Abstract*—The article provides an overview of personal and professional competence development in students of Elite Engineering Educational Program in Tomsk Polytechnic University, as well as procedures and criteria used to measure it, and provides a comparison of the resulting values with those of the students of traditional programs.**

Keywords—competence; competence-based approach; elite engineering education; psychological profile; proficiency level

I. INTRODUCTION

According to the requirements of Russia's Federal State Education Standards of the third generation (FGOS-3), educational programs of various levels and streams of study should shape a number of competencies in their graduates. This requirement is highly topical and demanded by both the time and market. For example, possession of the competencies necessary for performing professional duties is required from higher education graduates by the Russian Union of Industrialists and Entrepreneurs together with other unions of Russian employers.

The above-mentioned Education Standard defines competencies as abilities to implement knowledge, skills, and personal qualities for successful performance in various problematic situations in everyday life or professional activity.

In addition, works by Russian and foreign scholars contain various other definitions of competence:

Competencies are integral above-subject features of the trainees that manifest in readiness for performing certain activities in specific problematic situations during and after training [1].

Competencies are new internal psychological formations (knowledge, perceptions, action algorithms, systems of values and relations) that allow to perform activities according to professional and social requirements, as well as personal expectations [2].

A competence relies upon knowledge, is built through experience, and implemented by means of will [3].

Competence-based approach in education views its learning outcomes not as a sum of knowledge, but as a person's ability to act with expertise in various situations. This way, the focus is shifted towards forming necessary competencies in students, which means the development of their personalities, which also stems from various definitions of competence.

Personal competence is a system defining and conditioning a person's success in life. Personal competence belongs to the class of metacompetencies and lies within the foundation of all professional competencies. A person that is acting competently thereby creates a kind of space allowing to express one's competence.

A competence does not exist by itself – it appears as a specific new formation within one's personality under specific conditions.

Thus, the demand arises for a certain point where a personality that is ready to develop its competencies and a medium or space in which a person may act competently intersect, resulting in a whole new level of quality.

Since 2004, Tomsk Polytechnic University (TPU) possesses such crossing point in the form of Elite Engineering Educational Program (EEEP) that implies training engineering leaders capable of entrepreneurial and innovative engineering activity.

The program is implemented in parallel with the "traditional" General Educational Program (GEP) and includes preliminary selection of students with high intellectual potential, in-depth study of natural sciences and mathematics, economics, foreign language, and also the disciplines aimed at developing managerial and entrepreneurial competencies.

Training in EEEP consists of three stages: basic training (1^{st}–2^{nd} years), professional training (3^{rd}–4^{th} years), and special training. The tasks of each stage are interrelated and allow to achieve the set goal of shaping students' personal and professional competencies necessary for performing complex activities related to research, project development, and entrepreneurship.

II. PSYCHOLOGICAL PROFILING AND ANALYSIS

When developing the psychological profile ("psychological portrait") of an average first-year EEEP student the following techniques have been used: Thinking Style, Locus of Control, and the Hardiness Test.

978-1-4799-0152-4/13/$31.00 ©2013 IEEE 25-27 September 2013, Kazan National Research Technological University, Kazan, Russia

A. Thinking Style method

In the style of thinking an EEEP student is little different from the students of General Educational Programs (Table I).

TABLE I. GEP AND EEEP STUDENTS' TEST RESULTS ACCORDING TO "THINKING STYLE" METHOD

Thinking style/ Educational program type	Analyzer	Idealist	Realist	Synthetic	Pragmatist	Flat profile	Twofold style
EEEP student	52.5%	15.1%	18.4%	8.3%	12.8%	11.3%	18.4%
GEP student	51.0%	12.5%	25.0%	11.0%	18.0%	11.0%	28.5%

Predominant in both EEEP and GEP students of TPU is the analytical style, as is expected from an engineering university. Pragmatists and realists are more frequently encountered in "ordinary" classes, as these students are more aimed at obtaining a degree that would yield real feedback quicker, and prefer practical work to scientific activities and research. EEEP has larger numbers of idealists that can be characterized by a broader worldview, have increased interest in human goals, necessities, motives, and values. On the contrary, the number of synthetics with their contradictory thoughts is smaller in EEEP than in GEP classes.

Another indicator of personal competence is internality, i.e. viewing oneself as the reason for own success and failure [4]. It is determined with the help of Locus of Control technique.

B. Locus of Control

The Locus of Control (LC) test developed by J. Rotter (used here is the adaptation by E. Bazhin, S. Golynkina, and A. Atkind) allows to determine the level of subjective control of a student's personality, i.e. the degree of one's personal responsibility for one's actions and life. Under the internal locus of event control a person interprets all meaningful events in life as the result of one's own activity. Under the external locus of control a person believes all events in life to be the result of outside influence (other people, chance, higher powers). The level of subjective control is determined according to seven scales: general internality (I general), internality of success (I success), internality of failure (I failure), internality of family relations (I family), internality of professional relations (I work), internality of interpersonal relations (I interpersonal), and internality of health (I health). LC values over 5,5 sten (standard ten) in all scales indicate the internal locus of control, i.e. high level of responsibility for events in one's life.

Among the EEEP students average LC values range between 5,5 and 7 sten (except for values for professional relations and health) with only 19,6% of students having low (5% or less) LC values. This is explained by that the EEEP entrants are, as a rule, students with high Unified State Exam score and winners of various olympiads who have voluntarily passed the program's additional selection procedure and, naturally, have higher internality values. They are ready to accept responsibility for all spheres of their life.

EEEP freshmen display slightly lower internality values, especially in failure, while there are more students with low LC values (4 or less) among them. An exception is the internality of health value: Students from "ordinary" classes care for their health more (see Fig. 1).

Another important component of personal competence is the presence of a positive "I-concept", i.e. the feeling of being in control of one's life [4].

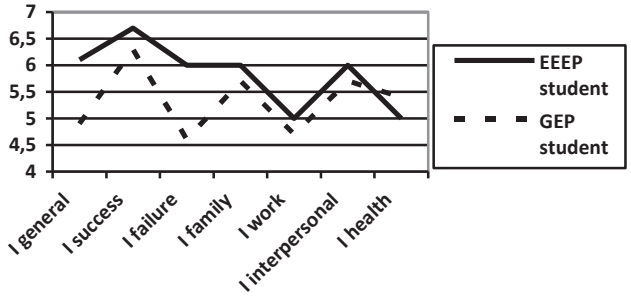

Figure 1. EEEP and GEP students' LC values.

C. Hardiness test

The psychological hardiness test (by Salvatore Maddi; adaptation by D. Leontiev and E. Rasskazova) includes three components:

- involvement – participation in activity and enjoying own work, feeling one's personal value;
- control – conviction in own influence on one's life;
- acceptance of risk – the ability to perceive events in life as challenge to own strength and capabilities.

This way, hardiness is a personal quality that allows turning new situations in life into new opportunities [5]. According to S. Bogomaz and D. Balanev [6], hardiness should be seen as a necessary component of a person's innovative potential.

The hardiness test was used to compare the results by students that failed their elite engineering training to those by the students continuing their studies (Table II).

Students that keep up with EEEP workload generally have all their values significantly above average, close to those of the winners of UMNIK ("Participant of the Youth Contest for Science and Innovation") National Program [6].

TABLE II. EEEP AND GEP STUDENTS' HARDINESS TEST RESULTS

Scale	Involvement	Control	Risk	Total Value
Average values	37.1	29.9	17.0	85.2
EEEP dropouts	36.1	31.6	18.0	86.2
EEEP students	41.0	37.9	21.0	100.0
Contest winners	43.5	36.1	21.8	101.4

It can not be unambiguously said that all students with low hardiness values can not withstand the load of EEEP. There are examples of the contrary, when students with high values leave and those with low values stay and improve them in the process of training. These students explain their motivation to master EEEP's demanding curriculum by its interesting educational and learner-centered environment that facilitates personality development.

III. COMPETENCE PROFICIENCY LEVEL COMPARISON

In the winter 2012 a research was conducted jointly with a Tomsk-based independent HR agency that diagnosed TPU students' managerial and entrepreneurial competencies using the "Resurs-K" expert system. Competence assessment was carried out comprehensively according to the results of several tests:

- social type determination – the peculiarities of a person's subjective interaction with the world (rationality – irrationality, extraversion – introversion; logics – ethics, sensorics – intuition);
- D. Holland test – determination of a personality's social orientation;
- psychogeometry – determination of a person's social type according to the peculiarities of one's behavior, speech, dressing style, and other easily observed parameters;
- LC – diagnosing the level of subjective control;
- General Aptitude Test Battery (GATB) – diagnosing the intellect structure and also the perceptive and sensory-motor abilities with the purpose of professional profiling and human resource allocation;
- Amthauer's intellect structure test to determine the IQ;
- ODK test – determining the presence of general business qualities.

Testing involved 104 TPU students including 55 EEEP students and 49 GEP seniors (4th–5th years). From among EEEP students 17 were seniors (17% of all EEEP seniors), and 28 were 1st-years (25% of all EEEP freshmen).

The test allowed to compare senior EEEP students to their counterparts from the traditional programs. As the result a number of common features were identified:

- high aptitude to research activities;
- high aspiration for status and leadership, ambition;
- low level of goal-setting;
- insufficiently developed skills of resource usage and creating conditions for achieving goals;
- insufficient faith in success, lack of charisma as force of example (can not entice people, fuel them with own belief).

Also identified were the relevant and significant differences between EEEP and GEP students in managerial and entrepreneurial competencies. The results of GEP and EEEP students' managerial profile analysis are given in Table III, and their entrepreneurial profile analysis is presented in Table IV and Fig. 2.

TABLE III. MANAGERIAL PROFILE COMPETENCE ANALYSIS

Traditional Education (GEP)	Elite Engineering Education (EEEP)
Planning	
Tacticians with down-to-earth substantiated goals	Strategists, inclined towards prospective, ambitious goals, not concerned with detailed work-through, assured that executives will be found. Interested in the result itself, not the process. Miss small things, details
Organization	
Authority	Laissez-faire
Motivation	
More flexible, adapt to others' opinion	More persistent, stand for their opinion
Control	
Revisionary control (find out who is guilty of the failure and punish). Authoritarian management	Analytical control (what failed, why? What needs to be changed?). Insufficient revisionary control due to high faith in people.
Decision-making	
Have more difficulty choosing from available options	Choose from all options with more ease, able to improvise
Communication	
Marginal communication style	More balanced communication, know how to communicate as equals

TABLE IV. ENTREPRENEURIAL PROFILE COMPETENCE ANALYSIS

Traditional Education (GEP)	Elite Engineering Education (EEEP)
Value stability, results	Value innovation, prestige
Tacticians	Strategists
Conservatives	Innovators
Prefer tasks of executive nature with clearly set goals	Prefer unconventional tasks
More business-oriented (ability to receive tangible feedback from investment)	More innovation-oriented (ability to experiment, study, start up)
More down-to-earth, strive for survival. Enter an environment and use this environment for their own needs, don`t mind manipulating. System is bound to a person, system is built upon personal connections	Aimed at the perspective, possess high intellectual potential. Systematic thought. First build a system, then find resources for it. Resources are secondary, they will be found, more important is understanding what for.
	Higher results of all intellectual tests Higher leadership ambitions Higher aptitude towards experimentation Higher proactivity Higher ability of persuasion and making contacts

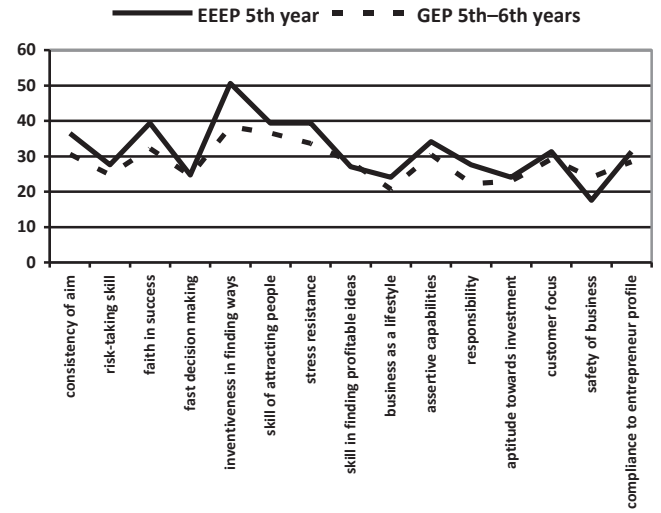

Figure 2. EEEP and GEP students' competencies in entrepreneurial profile.

Also within the framework of this research, testing and comparison of EEEP freshmen and seniors was carried out. EEEP seniors differ from the 1st-years in a range of parameters, including both the entrepreneurial profile (Fig. 3) and the manager profile.

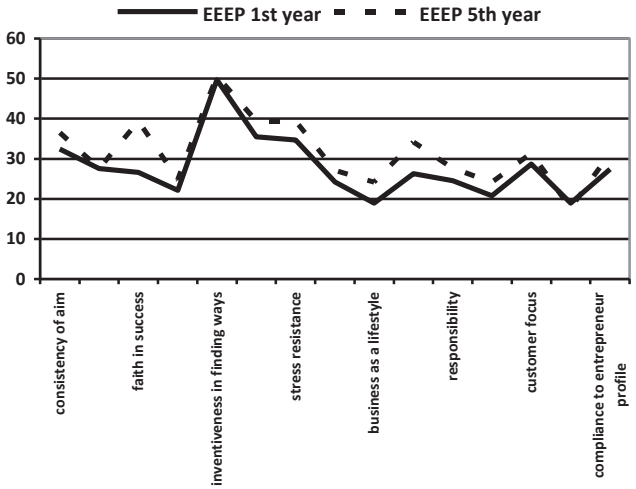

Figure 3. Entrepreneurial profile (EEEP students).

In their senior years EEEP students grow in assertiveness, faith in success, the ability to understand people and use their resource. Their stress resistance increases, as well as the ability to find ideas that generate profits. This allows for manifestation of pragmatism (business as a lifestyle), assertive capabilities, aptitude towards investing money, client focus (cooperation), and focus on the safety of common cause. As a counterbalance to all that, the risk-taking ability decreases along with the emergence of knowledge allowing to calculate risks, and freedom of thought decreases together with aptitude to invention.

Differences in general business competencies are also evident. During EEEP training students grow in insistency, obligation, and their skills of retrieving and processing information also increase. Seniors learn to better plan their activities, persuade, and make contacts. Self-confidence increases, and businessperson's ambitions emerge. The commitment to quality decreases (they have studied the system and learned how to use its deficiencies). This testing allowed to identify the problems in goal-setting, readiness to improvise, and quick making of well-considered decisions. In order to solve these problems it is intended to implement interactive (game) technologies in the training process.

IV. CONCLUSIONS

As the result of the executed research it was proven that the totality of personal and professional competence development results in EEEP students is higher than in their GEP counterparts. The research was carried out in two stages using different techniques:

Stage 1. Testing EEEP and GEP students according to Thinking Style, Locus of Control, and Hardiness tests.

Stage 2. Diagnosing EEEP and GEP students' managerial and entrepreneurial competencies using the "Resurs-K" expert system while employing the following methods and tests: determining the social type, D. Holland test, psychogeometry, Locus of Control, GATB, Amthauer's intellect structure test, and ODK test.

REFERENCES

[1] V.I. Zvonnikov and M.B. Chelyshkova, Kontrol Kachestva Obucheniya pri Attestatsii: Kompetentnostniy Podkhod: Ucheb. Posobiye [Education Quality Control During Evaluation: Competence-Based Approach: Textbook], V.I. Zvonnikov and M.B. Chelyshkova, Eds. Moscow: Universitetskaya Kniga; Logos, 2009, p. 272.

[2] I.A. Zimnyaa, Klyucheviye Kompetentnosti kak Rezultativno-Tselevaya Osnova Kompetentnostnogo Podkhoda v Obrazovanii [Key Competencies as a Result and Target Foundation of Competence-Based Approach in Education], Moscow: Issledovateslkiy Tsentr Problem Kachestva Podgotovki Spetsialistov, 2004, p. 42.

[3] Bolonskiy Protsess: Rezultati Obucheniya I Kompetentnostniy Podkhod (Kniga-Prilozheniye 1) [The Bologna Process: Learning Outcomes and Competetnce-Based Approach (Book-Appendix 1)], V.I. Baidenko, prof., D.Ed, scientific Ed. Moscow: Issledovateslkiy Tsentr Problem Kachestva Podgotovki Spetsialistov, 2009, p. 536.

[4] O.M. Krasnoryadtseva, "Metodologicheskiye osnovaniya issledovaniya myshleniya v realnoy (professionalnoy) deyatelnosti" ["Methodological rationale for studying thinking in real (professional) activity"], in Sibirskiy Psikhologicheskiy Zhurnal, vol. 5, 1997, pp. 33-38.

[5] D.A. Leontiev and E.I. Rasskazova, Test Zhiznestoykosty [The Hardiness Test]. Moscow: Smysl, 2006, p. 63.

[6] S.A. Bogomaz and D.Y. Balanev, "Zhiznestoykost kak komponent innovatsionnogo potentsiala cheloveka" ["Hardiness as a component of a person's innovative potential"], in Sibirskiy Psikhologicheskiy Zhurnal, vol. 32, 2009, pp. 23-28.