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Educational technologies for forming intellectual competence in scientific research and engineering business

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Abstract

The paper considers the problem of successful intellectual self-realization of engineering students. The results of experimental studies and data on the characteristics and level of students' cognitive development, courage in the formation of intellectual competence in scientific research and engineering business are discussed. In the paper the hypothesis of three levels (styles) of life activity and social interaction of the participants of educational process (maladaptive, adaptive and disadaptive) is introduced on the basis of the research conducted. The possibility of diagnosing, measuring and interpreting an optimal (maladaptive) education activity style as a condition of talent realization and creative mechanisms are discussed. This style tends to teach the students and professors how to use the most effective and flexible maladaptive communication based upon improvisation. A practical solution of this problem is possible if the classical educational models are supplemented by the educational technologies orientated at improvisation, assumptions and creative activity.

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Keywords: intelligence, intellectual competence, creativity, level of cognitive development, engineering business, innovative educational technologies, intelligent enterprise.

1. Introduction

Creating highly educational technologies is one of the most urgent problems of the beginning of the XXI century. Educational technologies preparing for a certain type of activity and training typical problems are not adequate to the existing conditions and risks of the information society. Training of specialists possessing the knowledge required for professional work and skills in accordance with branch and departmental regulations is unlikely to meet the challenges of our time.

Innovative educational technologies which meet the conditions and requirements of the modern society develop the ability to process information in a creative way and create intellectual products of high quality. It is intellectual

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competence and capacity for intellectual entrepreneurship which provide graduates with competitiveness in new economics, science and industry in the modern "society of knowledge." In turn, the efficiency of modern educational technologies should be evaluated in terms of the gained level of intellectual professional competence. The effectiveness of innovative educational technologies can be determined according to the criteria of intellectual development.

Innovative educational technologies require a profound meaning creating communication providing the opportunity for development. They ensure the formation of intellectual professional competence, the desire and ability to create new knowledge by solving the tasks of a new level of complexity. Professional competence is seen as internally motivated abilities that enable to work effectively and achieve meaningful goals in the professional field.

Sternberg (1999) showed that intellectual competence is a special type of organizing knowledge that provides the opportunity to make effective decisions in a particular subject area. The process of competence development involves simultaneous forming such basic intellectual qualities as intellectual initiative, intellectual self-regulation, and intellectual creativity. When the basic intellectual qualities are developed the habit of regular mastering the innovative techniques for searching and processing information is formed, an individual information infrastructure, which saves time and increases intellectual efficiency is developed.

Sternberg (1997) also demonstrated that the modern theory of intelligence enables measuring three basic components of knowledge-based information processing, namely, analytical, creative and practical skills. In the general intelligence theory the successful intellectual self-realization is associated with the features of the organization of mental experience of a person. It is the intellectual competence being a type of organization of subject-specific knowledge (and not the volume, depth or strength of the mastered knowledge) that enables making real intellectual achievements.

An extensive material in the study of intelligence does not allow specifying those components of cognitive function, which enable a person to use their opportunities in the most productive way. The success of highly intellectual subjects' self-realization is ambiguous, which is proved by a significant number of studies. The study of Sternberg et al. (2000) demonstrated that an outstanding contribution to the intellectual productivity is made by personal and motivational factors, ability to work extensively, specific features of self-organization and individual personality traits.

The issue of effective self-realization in the intellectual activity still remains relevant and insufficiently known. There are discovered the facts of successful learning and productiveness in scientific work of the students obtaining low values of IQ (90-98 points), or having slow and imprecise style of decision making in the situations of uncertainty.

All the peculiarities mentioned above indicate that intellectual abilities are in the complex nonlinear relationships, and in addition can have a cascading effect and appear both complex and single depending on individual circumstances or social influences (Sternberg, 2007).

2. Methods of study

In comparative empirical studies of a successful intellectual self-realization, the measurement and assessment of intellectual competence are becoming the most urgent. Standard psychometric tests that measure intelligence quotient (IQ) record only one aspect of individual activity aimed at finding the correct result only in accordance with the requirements of a given situation, i.e. converged abilities. According to this indicator alone it is not possible to judge about the intelligent features of a person and, moreover, to predict intellectual success and self-realization (Sternberg, 2008).

It is necessary to apply the methods enabling to assess the divergent abilities (ability to produce a wide variety of original ideas in terms of unrestricted activities) and the peculiarities of mental experience organization (Kholodnaya, 2012).

During the period from December 2005 to February 2014 we conducted a comparative analysis of an intellectual competence and individual cognitive style of the fourth-year students of TPU and TUSUR. The total sample comprised 130 people. The research studied the peculiarities of the knowledge organization (the level of

metacognitive experience) of the senior students of technical faculties. Metacognitive experience allows regulating intellectual activity and controlling the information processing.

The study identified two groups of students: “students intellectually successful in research activities” and students obtaining no achievements in science, but being “successful in the field of engineering businesses”. The identification of senior students as being intellectually successful in the research activities was carried out on the basis of their real intellectual achievements in the field of physics and mathematics (winning prizes in the contests on the studied professional area, research work, publication of scientific articles, and high academic performance).

The identification of senior students as being "intellectually successful in the field of engineering business" was carried out on the basis of the criterion of having outstanding achievements in the development and promotion of engineering projects in the field of machine building, instrument making, biomedicine, energy efficiency, telecommunications, aerospace and other engineering technologies.

The business ecosystem of a technical university is a complex system where different subjects work independently (students, teachers, management, departments and laboratories, temporary teams, engineering business representatives and other entities), engaged in entrepreneurial activity.

Intellectual entrepreneurship is the ability to see and influence the present situation through the perspective of the future. Intelligent enterprise is a complex characteristic of thinking and behavior. The ability to see the future through the perspective of the present provides:

1) adequate perception of the events;

2) consistent and comprehensive understanding of the situation;

3) adequate understanding of the partners "world view".

As a criterion of productive divergent performance the modified E. Torrance’s test was used (Torrance, 1974). In order to evaluate the features of intellectual activity within the framework of this test, the indicators of categorical flexibility (CF), originality (OR), constructive activity (CA) were used. Indicator categorical flexibility evaluates the diversity of ideas and strategies and the ability to move from one aspect of cognitive activity to another. Originality parameter characterizes the ability to put forward ideas that differ from the obvious, banal or firmly established ones. The criterion of constructive activity determines the degree of complexity and diversity of visual transformations performed.

The peculiarities of mental experience organization have operationalized into the parameters of certain cognitive controls’ level. The level of involuntary predictive control was assessed in terms of the indicators of the cognitive style "impulsivity - reflexivity" (the methodology "Comparing similar patterns" J. Kagan, 1966) and the indicators of the cognitive style "field dependency - field independency" (the methodology "Included figures" G. Witkin, 1977). Cognitive controls organize and coordinate the work of basic cognitive processes and limit the impact of affective and motivational states on the process of generating a cognitive image as well.

Convergent capabilities have been measured as the level of psychometric intelligence development in terms of intelligence quotient (IQ) by means of the R. Amthauera test (Amthauer Intelligenz-Struktur-Test, (IST).

3. The results of the experimental study

For processing and analyzing the materials of the experimental the methods of variance and cluster analysis were used. Variance analysis has revealed the significant differences in all selected indicators of intellectual competence among a group of students who are intellectually successful in scientific work and the group of intellectually successful students in the sphere of engineering business, Table 1.

Table 1. The significant differences in all indicators of intellectual competence

Group	Test								
	R. Amthauer			E.P. Torrance			J. Kagan and H. A. Witkin		
	IQ	IQt	IQv	CF	OR	CA	t	er	T
“intellectually successful in the sphere of engineering business”	106.6	103.5	108.3	6.2	14.2	11.6	33.3	10.6	14.8
“intellectually successful	118.4	121.6	115.6	7.5	21.6	19.3	49.0	9.7	10.9

in research activities"									
	Level of significance for R. Fischer criterion								
	0.01	0.01	0.01	0.04	0.01	0.01	0.01	0.03	0.01

As it can be seen from Table 1, a group of students "successful in research activities" has a higher level of psychometric intelligence and higher level of divergent abilities (creativity) in comparison with the group of "intellectually successful students in the engineering business". The indicators "average time of decision" (t) and "average number of errors" (er) in the Kagan's test show the differences by an impulsive/reflective cognitive style (a group of students "successful in research activities" are reflexive, the group of "intellectually successful students in the engineering business" are impulsive). The indicators "average seek time figures" (T) and "involuntary control" (nk) in the Witkin's test show the differences by the field dependency/field independency cognitive style (a group of students "successful in research activities" show field independency, the group "intellectually successful students in the engineering business" show field dependency).

Variance analysis does not comprise all factors of success while it only lists the psychological qualities facilitating a successful intellectual self-realization without giving their combinations. Therefore, the method of cluster analysis was applied in the research.

Cluster analysis was carried out by block parameters of psychometric intelligence (Amthauera's test) in combination with the following parameters:

- creativity (Torrance's test);
- cognitive styles (Kagan's test and Witkin's test).

In terms of Amthauera's and Kagan's tests clusters, whose characteristics are given in Table 2, were obtained.

Table 2. Cluster analysis by the Kagan's test and Witkin's test indicators

№ of cluster	Percentage of students in the given cluster	IQ	IQt	IQv	t, c	er	Distribution of students among clusters, %	
							"intellectually successful in research activities"	"intellectually successful in the sphere of engineering business"
1	26.90	116.3	121.3	111.3	30.3	13.3	31.5	68.5
2	38.46	100.1	100.7	99.5	39.3	9.5	3.4	96.6
3	11.97	102.6	99.2	106.0	23.6	21.8	0	100.0
4	16.67	120.6	122.5	118.7	57.0	5.8	54.5	45.5
5	6.00	109.8	108.6	111.0	42.5	8.7	0	100.0

Four clusters were allocated and the subjects of the group of students "successful in research activities" got almost exclusively into two clusters: the first and the fourth ones. Cluster 1 (31.5%) is characterized by high technical intelligence (IQt = 121.3), average time spent for seeking figures (time = 30.3 s), average number of errors (er = 13.3). Cluster 4 (54.5%) is characterized by high performance in relation to all three components of intelligence, greater time spent for seeking a figure (time = 57 s), the lowest number of errors (er = 5.8).

Table 3 shows the characteristics of two clusters obtained by analyzing the indicators of Amthauera's and Witkin's tests.

Table 3 Cluster analysis by the Amthauera's and Witkin's tests indicators

№ of cluster	Percentage of students in the given cluster	IQ	IQt	IQv	T, c	nk	Distribution of students among clusters, %	
							"intellectually successful in research activities"	"intellectually successful in the sphere of engineering business"
1	27.5	100.5	97.0	103.8	18.5	29.4	16.0	84.0
2	72.5	110.2	111.8	108.9	8.1	11.6	84.0	16.0

As it can be seen from Table 4, students belonging to the group of "successful in research activities" were mainly in the second cluster, which is characterized by high values of general intelligence (IQ = 110.2) and technical

intelligence (IQt = 111.8), the low value of the average search time image T (8 , 1), the average value of the index involuntary control nk (11.6).

The clusters allocated in terms of the Amthauera's and Torrance's tests are listed in Table 4.

Table 4. Cluster analysis by the Amthauera's and Torrance's tests indicators

№ of cluster	Percentage of students in the given cluster	IQ	IQt	IQv	CF	OR	CA	Distribution of students among clusters, %	
								"intellectually successful in research activities"	"intellectually successful in the sphere of engineering business"
1	56.3	105.3	105.3	105.3	6	12	11	22.0	78.0
2	43.7	117.2	124.2	115.8	8	22	19	78.0	22.0

Cluster 2 is characterized by a high value of technical intelligence (IQt – 124.2), high rate of constructive activity (CA - 22) and originality (RR - 19).

Thus, in the examined samples of students intellectually successful in research activities we have allocated students with:

– a high level of inductive reasoning (high rate IQt) and impulsive style of information processing (according to the Kagan's test);

– an ultra-high level of general intelligence (performance IQ> 120) and reflective style of information processing (according to the Kagan's test);

– a high level of general and technical intelligence and field independence style of information processing (by the method of Witkin);

– a high level of inductive reasoning, and a high level of constructive activity (an indicator of creativity by the modified Torrence's test).

4. Interpretation of results

With the help of variance analysis it was stated that high and very high levels of the general, verbal, and technical intelligence; a high level of creativity; field independency and reflexivity on cognitive styles assist successful self-realization in research activities.

Subgroups of students being intellectually successful in research activities, having peculiarities of organization metacognitive experiences and certain intellectual preferences have been identified on the basis of the cluster analysis. These groups complement and enrich the intellectual experience of each other.

The first group of individuals with high levels of inductive reasoning and impulsive style of information processing is different from a group of successful students who quickly and accurately solve algorithmic problems in the presence of established adequate cognitive schemes. A cognitive scheme is a set of generalized and stereotyped forms of storing the past experience with respect to a particular subject area (a familiar object, a certain situation, a usual sequence of events). It can be concluded that the adaptive level of life activity and social interaction prevails among the students of this group.

This group of study participants is more likely to act than to do the analysis. Their analysis of the problem is more shallow than deep and is based usually on their own similar experiences rather than on theoretical principles developed for problems solving. The advantage of quick response to the problem is that the conflicting opinions cannot slow down the process of solving it. Some professional problems require immediate removal. The required speed of action is quite different from the slow and reflective process of problem solving. The knowledge of the intellectually successful people of this sub-group is expressed not through words but through actions.

People with high levels of general intelligence and reflective style of information processing have such peculiarities of the organization of mental experience as intelligent self-control and self-regulation. The process of problem solving can be presented as a slow spiraling process.

Individuals with high levels of general and technical intelligence and independence style of information processing differ by successful analytic intellectual activity, ability to quickly identify relevant features, and characteristics of the problem without being distracted by minor, insignificant "sound effects".

Individuals with a high level of inductive reasoning and constructive activity possess the basic intellectual qualities such as initiative and creativity. They tend to search for new information, bring new ideas, going beyond the standard requirements of cognitive activity. This group with the prevailing innovative style of posing and solving problems is characterized by maladaptive level of life activity and social interaction.

Intellectual peculiarities of the group of students “intellectually successful in research activities” need to be studied deeper, to apply the new methods of assessment and evaluation. The interaction of these two groups in educational and professional activities is a condition and a factor of further intellectual development and social activity.

These results give the possibility to use the diagnosis of mental processes and intellectual abilities of students to assess the effectiveness of innovative educational technologies forming the intellectual competence. The identified subgroups allow the development of innovative educational technologies focusing on creating intelligent and creative teams of groups forming the communicative competence for the successful solution of professional problems together with other people. Communicative competence determines the effective interaction of people with different intellectual preferences and different views on the issue.

Generating and developing intellectual competence and maladaptive level (style) of the life activity and social interaction is the reason why a new type of the educational technologies should be created. The business and management school teachers who are ready to create and realize innovative educational technologies are as a rule the professionals having great experience of research and teaching work.

The focus of their scientific interests is on the real economic, social, and psychological collisions, practical problems, the problems of business and management. They are skillful in the field of applied and consulting research. There are two ways of applied research: using the research methods for the denial of general ideas or for supporting a new not obvious business and management experience. The topics of such investigations are of interdisciplinary approach, practically oriented, morally meaningful, and include the demonstrable examples of problems in management.

The innovative education technologies tend to form professional skills and develop unique abilities, which are required for the modern business and management. Let us discuss some of them.

1. Ability to select a problem, to take a practical efficient solution, to analyze consequences of solutions, which are, as a rule, made in very complex situations.

2. Ability to make decision while there are no full, accurate, and mutually connected data, to collect new data when there are no sufficient time and adequate circumstances. Hence, it is very important to improve your ability to interpret the facts and take decisions properly when the circumstances are hard and the data are few.

3. Ability to use quality and quantity data for making correct decisions. It is a situation when statistics and strict scientific analysis methodology become subsidiary when opposed to the situation when they play the main role. Investigation and knowledge of tendencies and laws are very important for analyzing the real situations in business and management.

4. Solution of the business and management problems does not allow using only limited special knowledge. The financial problems are connected with marketing, selling, producing, and moral norms. The specific circumstance analyzing permits to understand the multilayer situation structure, hidden strategic, economic, concurrent, political, and psychological sides.

5. Ability to creative thinking and analyzing. It is known that stereotyped solutions and preferences lead to inadmissible professional blunders. It is very dangerous to transform the management technologies, which generalize a successive experience into solution patterns.

6. It is very useful to doubt your resumes and solutions, to be ready for quick repairing perception blunders, for warning the “absolute” resumes and solutions.

The basic ideas and principles of the innovative education are:

1. The education efficiency basis is directing education to making collective decisions of the mutual problems.
2. Education is a kind of a research activity.
3. Innovative education is always a human being or human society evolution
4. An intense exposure is the basic form of the innovative education.
5. The innovative education is built in accordance with the idea that all the people are talented from their birth.
6. The education process is built on the Cartesian principle: from complex to simple.
7. The innovative education logic consists in motion from an action (practice) to knowledge and conceptions.
8. The knowledge is not given from outside but is grown up in a human being consciousness on the basis of large volumes of information.
9. In the process of an innovative education, the reserve activities of our consciousness, psychic, and thinking are maxim activated and involved.
10. The process of the group intensive growth promotes the education and development of pupils.

The innovation education tends to use the teaching methods and solution of problems based on the specialists' erudition and intuition. These methods are the brain attack, scenario method.

5. Conclusion

On the basis of the study it was found that the formation of certain psychological qualities assists in successful intellectual self-realization. It includes intellectual creativity (the process of creating something that is subjectively new, the ability to generate original ideas freely and to go beyond the standard requirements of reality), intellectual initiative (the desire to seek out new information on their own, come up with new ideas), intellectual self-regulation (reflexivity, field independency, the ability to manage their own intellectual activity.)

The results indicate that these metacognitive abilities show independence and reflexivity, allow objectified forms of mental representation (objective forms of mental representation of the events), which, in turn, contributes to the successful intellectual fulfillment.

To assess the intellectual competence and forecast intellectual success it is not enough to use traditional psychometric tests that measure IQ and fix only one aspect of individual activity. It requires holistic assessment of technology convergence, divergent and metacognitive abilities as factors of intellectual competence. This technology allows us to identify and take into account individual features of intelligent students as well as to enrich the "repertoire" of intellectual behavior of the future specialists. Intelligent self-realization and self-development are targets and performance criteria of innovative educational technologies of forming professional competence.

Intelligence is a psychic system, the total capacity for mental activity. The level of organization of mental experience and the structure of mental experience are the results of the psychic system functioning. Thinking is the process where the intellect is implemented. It is the indirect and generalized knowledge of objective reality. The indirect knowledge means that it extends beyond something that is given directly. Thinking is considered to be a form of knowledge. Knowledge acts as the creation of representations of the external world, its presentations, models, and images. The basis of thinking is building a representation of the problem situation. The main thing to be considered is the very formulation of the problem.

An individual does not receive knowledge from the outside. Cognition begins "from the inside": an individual formulates a hypothesis and gives his question to the world. The answer that the individual receives is given in the language of this hypothesis. But that's not all. This response is interpreted by the individual (again, in terms of the hypothesis). We would like to add that the latter interpretation must still be consistent with an interpretation constructed earlier, not only to adjust to them, but also to change them. Here is a dynamic structure of interrelated interpretations created in the process of individual development, and it represents so called "knowledge of the world". The individual may have a high cognitive complexity in one content area and a low one in the other.

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