Influencing engineering education through the competency-based approach

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Abstract. The article poses a problem of engineering education and training of today, which are facing difficulties while developing an efficient competency-based approach realization. The authors concentrate on an urgent task of developing the integration competence of future engineers which is treated as a metadisciplinary competence providing students with ability and readiness to synthesize subject-oriented professional and social competences into a holistic system. The structure of integration competence is analyzed and the following components are determined: a value and motivation component; a practical activity component; a cognitive component; a self-analysis and self-assessment component. Among distinguishing features of the integration competence the authors define its instrumental character, metadisciplinary and universal properties as well as its nonalgorithmic character. It is shown that professionally oriented training is a core factor of integration competence development. Depending on elements being integrated, the main forms of integration of competences are determined. The model of competence integration presented in the article can serve as the basis for developing methods and conditions for its systematic elaboration in university training. The results of this study can be useful for educators of different administrative levels, teaching-and-training schools which realize a competency-based approach in their teaching.

1 Introduction

Engineering education and training of today, being potentially able to develop an efficient competency-based approach realization, does not demonstrate flexibility or willingness to create mechanisms for its realization, and sometimes can be marked as hampering beginning engineers' career paths [1]. Three key problems were identified as crucial to engineering education.

First of all, a great many of engineering schools do not train suitably qualified people with any sufficient hands-on experience.

Secondly, educational services markets tend to promote short-term marketable products without consent of long term prospects for the purpose of regional labour markets development strategies [2].

Thirdly, the modern youth labour market goes through a growing rift between career aspiration of beginning engineers and lack of ways to satisfy their anticipation. As long as beginning engineers do not have enough industrial apprenticeship to satisfy employers with the adequacy of their engineering skills, they become unwanted to fill vacancies [3].

The observation is that more and more businesses are reporting difficulties in recruiting skilled workers they need to occupy jobs. Furthermore, manufacturers expect the problem to escalate with two-thirds of manufacturers predicting difficulties recruiting production staff in the next five years. This concern is shared by all companies, regardless of the size or sector [4].

In the Russian Federation a competency-based approach in engineering education is currently considered to be an ultimately efficient approach to teaching and learning concrete skills rather than abstract theoretical knowledge. A competence profile of a professional suggests a set of cultural and special competences which, taken collectively, provide his/her ability and readiness to operate effectively according to varying requirements in a particular context [5].

This approach sets up a problem of integration of specific competences in order to achieve the main purpose of professional training that is developing the professional competence of graduates and enhancing their career path. There are a number of inconsistencies

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in the current university practices which make this task especially urgent [6]. They are inconsistencies between an integrative character of professional activity and a subject disciplinary way of professional training, between a conceptual focus on interdisciplinary integration based on synthesis of scientific knowledge and insufficient use of pedagogical integration in the university education process, between increasing requirements of employers to the professional qualities of specialists and the actual level of their competence.

In view of the above-mentioned, the purpose of this work is to define and describe the personality mechanism which enables students to combine and integrate competences in the course of their university training as well as in their future career.

2 Methodological Framework

2.1 Methodological grounds

So how might one scientific school vision be fundamental upon the competency-based education in engineering schools including assessment of engineering academic courses, research involvement, and intake for industrial apprenticeship, since we can build upon the significant knowledge base provided by the recent studies conducted by organizations such as National Academies, Science and Economy Committees, engineering professional societies and associations?

It is of vital importance to combine these analyses, conclusions, and recommendations into a ground breaking strategy for the revamp study of a competency-based engineering education.

There are many possible approaches to such an effort. The most advantageous are comparative, systematic and analytical research methods.

2.2 Literature review

During the past several decades numerous studies have suggested the need for a competency-based paradigm in engineering practice, research, and education that better address the needs of a 21st-century global, knowledge-driven society. A survey of research papers devoted to problems of engineering education reveals a great number of works which deal with particular competences development problems as essential parts of the integral professional competence of future specialists. Most prominent among these works are: Gene E. Hall (1976) Competency-based Education: A Process for the Improvement of Education [7]; Susan V. Monjan, Suzanne M. Gassner (1979). Critical Issues in Competency Based Education [8]; John Burke (1989) Competency Based Education and Training [9]; Bartram, D. (2005) The Great Eight competencies: A criterion-centric approach to validation [10]; U.S. Department of Education (2012). Competency-Based Learning [3].

Theoretical results and methodological developments achieved by the authors of these works enrich pedagogical science and teaching practice with comprehensive understanding of structures and substructures within professional competence, methods and conditions for their development. However, European educators use the competence concept in an integrative manner. The authors of the European Qualification Framework define it as “an expression of the ability of individuals to combine – in a self-directed way, tacitly or explicitly and in a particular context – the different elements of knowledge and skills they possess” [11].

Many researchers recognize the problem of finding forms and ways of synthesizing competences. In work [12] the authors analyze the structure of integrated competence and distinguish structural and functional parts. The structural part consists of knowledge, skills and personal characteristics which determine human behavior in personal and social life. Functional part of the integrated competence includes integrative informational and integrative activity components. According to the authors the first one allows treating the integrated competence as a system of theoretical, methodological and professional information which must be learnt. In such a case integration of this content, realized in particular with the help of intersubject communications, plays a very important role. The other component described as integrative activity one suggests that integration of activity methods is strongly required in the process of building up the integrated competence as far as competences are not applied independently for solving professional problems but in interaction and cooperation with each other. Thus the authors believe that ability of a specialist to combine competences is essential.

Integrative competence is treated by some authors as ability of a specialist to tie up theory and practice alongside with understanding of the broad cultural, economic and social context within which professional activity takes place, which is to combine specific and unique with common and universal [13,14].

Another approach to the problem of synthesizing specific competences consists in distinguishing interdisciplinary competence. This concept is worked out in a number of research works. According to work [16] development of interdisciplinary competences defined as an ability to synthesize scientific knowledge, to view all things and events in their interaction and development provides for further efficient professional performance of engineers in the situation of fast change of job content and job requirements. Besides knowledge, abilities and skills, the author includes a number of personal qualities into the structure of the interdisciplinary competence: understanding interrelations between scientific disciplines and ability to apply knowledge obtained within one of the sciences for studying others; experience of complex application of knowledge obtained within one of the sciences for studying others; an extent of purposeful use of knowledge in professional activity when the interdisciplinary approach is required; students’ self-confidence in solving professional problems using complex knowledge of different disciplines; a good command of information technologies [15].

This kaleidoscope of evaluations and initiatives is likely to cause very significant changes in engineering education over the next several decades.

3 Results and discussion

3.1 Definition, Functions and Features of Integration Competence

Thus, as we can see, the problem of integrating knowledge and skills together with acquired job methods and useful personal traits in the process of professional training draws attention of many researchers. Generally they consider students' ability and readiness to combine knowledge and work methods as a metadisciplinary competence which is necessary for achieving a holistic educational result. We will designate this personality characteristic as integration competence and will define it as a complex of interrelated personal qualities which provide for human ability and readiness to combine and integrate separate professional and social competences into a holistic system – an integrated professional competence.

The relevance of the notion "integration competence" which we have just introduced justifies the following considerations:

- the competency-based approach is now an accepted instrument for description and proper assessment of educational results;
- the professional competence as the aim of specialists training is integrative by its fundamental nature;
- purposeful and systematic actions aimed at developing students' ability and readiness to combine subject knowledge and work skills are necessary to achieve an integrated result of professional training.

The integration competence is of a special character as compared with other competences defined by the Federal State Educational Standard as it does not exist independently. Its function is to accompany the process of acquisition and development of new competences so that they could be combined into a system. At that the integration competence "works" continuously in the course of extending and enriching knowledge and practical components of professional competence and by doing so it is also being extended and improved.

The integration competence must actuate an imminent ability of a person to recognize and reproduce interlinks between natural and social facts and processes, to perceive the comprehensive basis of any activity. Being a part of professional competence the integration competence fulfils a number of important functions.

- The function of selection and assessment suggests choosing and ranging knowledge and practices to be involved into the focus of attention and consideration for further learning and interiorization.
- The function of systematization provides finding links and relations between the selected parts of scientific information and social experiences, their integration in a hierarchy system.
- The function of adaptation means appropriate use of the acquired knowledge and skills in practical work.
- The function of personal development subjects all other functions and consists in intentional personal transformation which provides for achieving professional goals.

Among distinguishing features of the integration competence in the first place we can name its *instrumental character* meaning that it presents methods and techniques providing a desirable result. The instrumental character of the integration competence implies its *metadisciplinary and universal properties* which consist in using theoretical knowledge and practical methods from different subject areas through certain intellectual operations. Another important feature of the integration competence is its *nonalgorithmic character* taken as an ability to deviate from a conventional procedure, to find unstandardized solutions, to apply heuristic ways of doing things.

3.2 Structure of Integration Competence

For integration competence structure analysis we have adapted the competence model developed by I.A. Zimnaya [16]. The following components have been determined: *a value and motivation component* (readiness to exercise and manifest the competence, attitudes to its nature and to objects of professional activity); *a practical activity component* (experience of applying the competence in different context); *a cognitive component* (mastering the knowledge involved into the competence); *a self-analysis and self-assessment component* (after action review, recognizing responsibility for the results).

The value and motivation component of the integration competence suggests that future specialists understood an integral aim of their learning in the university as well as throughout life; had positive attitude to interdisciplinary integration; pursued the objectives of systematization and harmonization of interdisciplinary knowledge and of utilizing various methods for solving professional tasks; had ambition for personal growth through combining the acquired competencies into an integral whole – the integrative professional competence. Proper values and high degree of motivation mean that a student is psychologically prepared to master theoretical and practical knowledge in neighboring subject areas for fulfilling professional tasks, ready to self-realization in various types of professional activity.

The cognitive component joins knowledge of general scientific and philosophical principles of the universe; builds up a holistic world view; provides awareness of the main principles of integration and knowledge of integration methodology.

The practical activity component suggests a grasp of integration techniques (such as comparison, association, abstraction, categorization, typification, individualization, assimilation, accommodation); experience of independent integration of knowledge; experience of solving problems in a professional sphere with the help of integrated knowledge and methods.

Self-analysis and self-assessment in the course of developing the professional competence is an important element of the integration competence. Students should be able to compare and coordinate the obtained educational results with the desired ones, to analyze and evaluate their educational and social experience. These skills contribute to self-control and self-regulation; allow independent correction of an educational route in building up the integrated professional competence.

We believe that all participants of the educational process should understand the role and the character of integral links inside the system, the importance of their purposeful stimulation and development. This understanding stipulates the effectiveness of developing professional competence as an integrative system of knowledge, skills and personal qualities. With this aim in view it is necessary to explain and demonstrates to the students how elements are combined into a system, how insignificant properties of integrated parts are lost and new properties are acquired by a system. As far as integration and differentiation are closely connected, it is also important to study differentiation processes, to show mechanisms of decomposition and analysis of a whole.

Acquiring integration competence will allow future professionals obtain new quality of knowledge, which can be characterized as systematic and interdisciplinary. As a result they will be able to find and adapt elements of integrated knowledge in the course of professional activity. The integration competence supported by strong motivation to the profession is an important factor of improvement and extension of the professional competence.

3.3 Principles of Integration Competence Development

The analysis of the structure and special features of integration competence carried out herein above helped us determine pedagogical principles which underlie the mechanism of development of this personal quality in a higher educational institution.

From a dialectic viewpoint, integration and differentiation are inextricably interrelated. Separating integration from differentiation deprives it its status as a self-consistent scientific notion. This consideration stipulates the principle of *unanimity of integration and differentiation* in the process of developing the integration competence. This principle prescribes separation of the whole (professional competence, professional knowledge, scientific worldview) into components (subject competences, elements of professional knowledge and of scientific worldview) with the purpose of step-by-step study and acquisition. Psychologists found out that personal development in the course of professional activity is of pulse character with latent periods of collecting differentiated knowledge followed by so called “integration bangs”, which bring a person to a new level of personal development. In other words, in the process of developing professional competence, stages of learning separate knowledge elements, methods of work, motives and values are succeeded by stages of their integration into a system and changing the system qualities. Thus, the principle of unanimity of integration and differentiation can be traced both at the level of educational content and at the level of personal learning activity.

The principle of *personal orientation* in the developing integration competence is born by its definition as a personal quality, which makes possible independent individual search of integrating ways and methods. The principle of personal orientation places a student into the center of the educational system, makes her/him a subject of integration processes. The main point here is a supposition that each person is unique, inimitable and potentially talented, and this should be developed. That is why the purpose of teaching is not to present a ready system of knowledge (which is, in fact, impossible within subject discipline oriented system) but to lead students to synthesizing and integrating new information, to build up conditions for interdisciplinary understanding of problems and for integration of distant ideas in creative professional activity. They should show that the same thing can be involved into different complexes, be a member of different relations. With these ideas students will be able to build a holistic system of knowledge independently in their individual unique way.

The principle of professional orientation of the developing integration competence is derived from the integral purpose of professional education which consists in training competitive specialists able to solve professional problems effectively. The principle of professional orientation suggests systematic use of teaching tools and methods providing development of professionally relevant personal qualities, motives and values of a future specialist as well as interrelation of specific professional and fundamental knowledge.

The principle of systematic and continual development is an essential requirement of training success. According to this principle the content and methods of integration competence cultivation should correspond to the logic of scientific integration and to the logic of professional activity.

3.4 Integrating Basis

In order to work out a technique of building up the integration competence as a part of university education it is important to analyze and describe how integration of competences works, its ways and mechanisms.

As it was said above, professional competence is taken as an integral system, that is the system which is characterized by a hierarchy structure of elements, has a core factor which determines integrative processes providing efficient performance of the system. Determining the core factor “defines the concept of a system as it is as well as the strategy of its application in research work”. [6] A purpose which causes birth and performance of a system (or its useful result) generally acts as the core factor of the system. It is sufficiency or insufficiency of the result (i.e. reaching the purpose) which determines system behavior. As a rule the purpose

emerges from a problem situation which cannot be solved with available means. In the case being considered the problem situation and consequently the core factor can be found in adequate, socially appropriate performance of professional tasks or, broadly speaking, efficient professional activity. Thus, intensive orientation at a professionally important educational result is the focal point. Only this approach can lead to building up professional competence as an integrative personal quality.

An important step in the study of integration competence with the view of creating a technique for its development is finding an integrating basis which should be involved into educational process. In other words we should define which system elements should be integrated on different levels of training. We have determined the following forms of integration of competencies.

Methodological integration is based on application of methods common in different sciences for solving professional problems. The range of such methods is very wide: survey, comparison, experiment, systematization, scheming, categorization, interpretation, explanation, idealization, formalization, and others. There are also interdisciplinary methodologies involving various specific methods. As an example we can name decision making and problem solving techniques, contextual analysis.

Humanitarian and axiological integration provides for finding common humanitarian problems in all knowledge areas as well as in research and production activity. It implies developing humanitarian culture, which in particular includes developed reflection and self-analysis alongside with the ability to apply value categories to the process and the results of professional activity.

4 Conclusion

It is supposed that in mastering a profession in practice, job experience will evidently encourage graduates to combine and integrate competencies developed during university training independently by trial and error method. But it prolongs the process of young specialists' adaptation at job, worsens their efficiency. That is why it is important to overcome disciplinary integration and separate development of specific competencies in university training. We are of the opinion that the integration competence is an effective personal tool for providing a holistic quality of professional competence. The structure, functions and special features of the integration competence described herein above can serve as the basis for working out methods and conditions for its systematic development in university training.

The results of this study can be useful for educators of different administrative levels, teaching-and-training schools which realize a competency-based approach in their teaching.

According to the research results, a wide range of scientific problems might be highlighted for further investigation: the extension and thorough research of some theses specified in the article related to creating a system of advanced competency-based training; the development of methods of advanced competency-based vocational training management based on the interaction between universities and businesses and its consolidation in educational systems.

References

1. *Educating tomorrows' engineers: the impact of Government reforms on 14-19 education /Seventh Report of Session 2012–13,* 7-36 (2013)
2. Jobs and Growth, *The importance of engineering skills to the UK economy* (2015)
3. *Review of vocational education – The Wolf Report,* (2011)
4. J. Duderstadt, *A Roadmap to the Future of Engineering Practice, Research, and Education* 3-8 (2008)
5. R. Boyatzis, J. Manag. Develop, **27(1),** 5-12 (2008)
6. P.K. Anokhin, *Principy sistemnoj organizacii funkcij* (1973)
7. H. Gene E., J. Howard L., *Competency-based Education: A Process for the Improvement of Education* (1976)
8. S. V. Monjan, S.M. Gassner, *Critical Issues in Competency Based Education* (1979)
9. J. Burke, *Competency Based Education and Training* (1989)
10. D. Bartram, J. Appl. Psychol., **90(6),** 1185-203, (2005)
11. V. Vathanophas, Contemporary Management Research, **3(1),** 45-70, (2007)
12. S. I. Tormasin, N. P. Puchkov, *Voprosy sovremennoj nauki i praktiki. Un. im. V.I. Vernadskogo* 1(37), 149 – 158 (2012)
13. S. V. Shmachilina, *Sovremennye napravlenija razvitija pedagogicheskoj mysli i pedagogika I.E. Shvarca*, 208 – 214 (2009)
14. A. A. Nikitin, M. P. Paljyanov, M. V. Morozova, A. S. Markovichev, International Review of Management and Marketing, **6 (1),** 75-80 (2016)
15. E. I. Shangina, *avtoref. diss. ... dokt. ped. nauk* (2010)
16. I. A. Zimnjaja, *Kljuchevye kompetentnosti kak rezultativno-tselevaja osnova kompetentnostnogo podhoda v obrazovanii* (2004)