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Competency-Based Model of Nanotechnology Specialist's Profile (Kazakhstan's Experience of Nanotechnology Education)

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Abstract: The study presents organizational experience of Nanotechnology Education (NTE) in Kazakhstan, oriented on Competency-Based Model of modern specialist's profile. The model determines reference points of appropriate education based on real Nanotechnology (NT) development. Although, modest the scale of NT development in Kazakhstan is growing as it is the government's key priority and interest to achieve an industrial-innovative breakthrough. This is evidenced by the initiatives and state programs as well as substantial funds allocated with the objective to match countries with highly competitive economies. In this case, the main question of NT development in Kazakhstan becomes: how is it possible to accelerate and develop NTE in weak NT market conditions and uncertain demand from employers? The purpose of the research conducted was to develop professionally required NT specialist's competencies which would be able to serve as a guidance to those who prepare specialists capable of working in knowledge-intensive industries including NT. Methodologically substantiated approaches for the creation of a future NT specialist's profile were used in close connection with the requirements of scientific schools operating at the universities. Competency requirements imposed by scientists within scientific schools were taken as the main purposes of NTE. Main characteristics of specialists in the form of competencies matrix were reflected in purposes and tasks of educational programs of NTE that contain a specific set of study disciplines used by engineering course designers. As a result, it was possible to ensure purposeful training in transition period of the formation of NT branch.

Key words: Nanotechnology development in Kazakhstan, nanotechnology education, competencies, nanotechnology specialists profile, NT branch

INTRODUCTION

NT development is in large part caused by the increasing demand for new materials arising from global exhaustion of raw materials and fundamentally new properties of nanotechnology products. "Today any country in the world cannot be technologically competitive and create their intellectual property in science and technology without nanotechnology development" (Abdymomunov and Bekturganov, 2006).

Numerous publications on nanotechnology development in recent decades demonstrate a wide understanding of nanotechnology as being closely linked with global economic trends in economy, increased competition and rapid technological changes. "Nanoscience and nanotechnology" involving the engineering of materials, devices and systems at very small scales "have emerged as important priorities not only for science but also for economic development" (Klochikhin and Shapira, 2012). Correspondingly, new requirements for modern specialists in nanotech industry have appeared, meaning that modern specialists now have a wide range of professional competencies and creative characteristics to fulfill.

Kazakhstan's nanotechnology market is not yet fully formed but there are already several research groups conducting research and development of synthesis of nanoclusters and nanostructures of semiconducting and metallic systems as well as developments of nanoscale catalysts, sensory nanostructured materials and carbon nanostructures. Nanotechnological products have not yet had widespread commercial production and elements of nanotechnology market are still unfolding. However, any nanotechnology development has a potential to cause an enormous social effect as it demonstrates the progress of domestic production and market economic prospects of the country.

There is close attention and huge interest from Kazakhstani government who has supported domestic

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developments and new initiatives and projects, especially if they are closely linked with commercial production. The Kazakh National Nanotechnology Initiative (put in place as a direct consequence of innovative processes ongoing in the national economy) seeks to accelerate national nanotechnology development and advance appropriate nanotechnology education. International links and collaboration between scientists gave start to development of Kazakhstan's initiative in nanoelectronics (Mun, 2010). According to Kazakhstani scientists, "currently, nanoelectronics represent a certain bank of ideas which are used only to minimal degree in Kazakhstan's industry. They consider "this circumstance as an opportunity for Kazakhstan to grasp its place in international division of labor in this sphere of science as countries possessing various degrees of technical development in nanoelectronics are in approximately identical situation". Physical chemistry of hydraulic polymers is considered as a scientific basis of Kazakhstan's initiative in nanoelectronics. "Kazakhstan's physics and chemistry schools traditionally held strong positions without being inferior to research of most of the developed countries. It is therefore, possible to realize breakthrough on that corresponding base". Achievements of scientific schools in hydrophilic polymers are considered as a reliable basis for subsequent steps in nanoelectronic development.

There are sufficient examples (production of new organic mineral fertilizer, nanocapsules, nanodispersed powders, etc) which partially characterize NT development in Kazakhstan, its real scientific and technical potential, significant experience of activity of scientific centers, organizations and universities actively involved in nanotechnology, confirming real prospects of development oriented on globally progressive levels. Hence, the development of science and education in nanotechnology sphere is highly unlikely to cease, despite the uneven development of individual areas of scientific and technological market.

NANOTECHNOLOGY EDUCATION IN KAZAKHSTAN (THE CASE OF KAZNTU)

Since, nanotechnology is considered as one of the priority directions of science and industry in Kazakhstan in order to ensure the diversification of the economy and sustainable development of the national economy as a whole there is an urgent need for preparation of competitive, highly qualified specialists with a grasp of long-term trends of the industry who are able to engage in large-scale research, participate in high-tech projects, solve new challenges of science and production. In this regards, certain results of research and development have already been achieved and are able to impact the learning process accordingly. Moreover, the accumulated scientific potential of the universities can be considered as the base for upgrading of educational programs in order to train of specialists in science-intensive sectors.

As such directing education towards results and achievements of domestic science and world experience led to an upgrading of educational Postgraduate programs in nanotechnology at Kazakh National Technical University (KazNTU). Introduction of disciplines in accordance with research subject within the frames of scholar schools operating in the university gave opportunity to form much needed competencies for future specialists in nanoscience and nanotechnology.

The term "scholar school" implies "a system of scientific views as well as the scientific community which adheres to these views". Scholar schools normally have the founder and his followers. Such schools can be formed as part of the framework of academic departments, research organizations and professional associations of scientists. Several scholar schools can simultaneously solve the same scientific problems but theoretical foundations (principles) and practical approaches to problem-solving (both tools and methods) may differ. This explains the high diversity and range of results achieved by scientists from different scholar schools.

In our scenario, a scholar school implies a group of scientists who specialize in a certain issue in nanotechnology. Within the school there is continuity of research traditions from generation to generation which coupled with specialization is able to provide significant scientific results. A young scientist joining a research team of a particular school rapidly acquires the knowledge and skills necessary to carry out certain studies. It is easier to gain access to important sources of information and learn existing ones. Scholar schools may merge in research areas and directions.

Scholar schools define the context in which NTE is realized-predominantly for postgraduate and doctoral levels. In reality, scholar schools create the necessary conditions for NTE realization that must have reference points as specialist's competencies presented in the model. Achievements and results of operating scholar schools are to be reflected in disciplines, research work and diploma as well as in any future professional activity. Aside from this scholar schools form the environment in which an innovative person is able to learn to quickly adapt to the ever-changing circumstances of the economy and technological progress.

Scholar schools under guidance and leadership of professors can ensure intensification of activity due to creation of laboratories, usage of unique scientific equipment (instruments, devices, measuring systems, etc). Within each scholar school collaboration and partnership during joint research may develop and as a result modern specialists oriented on international standards of activity having progressive views and ideas develop.

It is important to note that the presence of different directions of nanotechnological activity in Kazakhstan has caused the necessary differentiation of training by application areas such as nanoelectronics, chemical, mining industry. That is dictated by the priorities and current state of scientific and technological development in Kazakhstan due to the ongoing need to diversify the economy and give new impetus to economic development. If nanotechnology applications of the likes of nanoelectronics and chemical industry are traditional for this sector then introduction of mining industry as the direction of NTE can be explained by the fact that the mining sector has historically served as Kazakhstan's key industry. This has been evidenced by the Kazakh roots and origins of some of the world's largest mining companies such as Kazakhmys (prior to 2013-ENRC) listed on the London Stock Exchange. Moreover, mineral raw material can be considered as nanosystems where boundaries between the components of the mineral (quartz, magnetite) are nanoobjects. For instance, nanotechnologies are widely used in mining activities of companies in Canada, Australia and South Africa.

A study of international experience of NTE has shown that for most countries, it is characterized by a combination of fundamental training on natural science and modern engineering training focused on innovation in technology (Cowan and Gogotsi, 2004; Vogel and Campbell, 2002). Preparation of specialists in this area often does not cover all stages of education. For example, some universities in the UK and France do not offer courses below Master's degree in NTE. Postgraduate students can be credited with a Bachelor's degree by one of the natural sciences or engineering disciplines but not necessarily nanotechnology. Several British universities offer so-called integrated program of Bachelors and Masters degrees merged into 4 years duration of training. Students mastering the program are awarded with a Masters degree in nanotechnology. Ph.D study in nanotechnology is presented in almost each technical university of the EU, even if there are even no educational programs for Bachelors and Masters in nanotechnology (Examples: University of Oulu, Finland; UCL and Imperial College of London, UK; several Universities in Germany, Denmark, Switzerland).

On the whole in Kazakhstan, NTE relates overwhelmingly to post-graduate courses (preparation of Masters and Ph.D but not Bachelors). Educational programs for Postgraduate and doctoral levels consist of mandatory courses and original individual research (State Obligatory Standard of Education of the Republic of Kazakhstan). Their focus is primarily on mastering of the methodology and methods of research and its active and skillful implementation. Alarmingly, there is no nanotechnological system of education of the likes Mahbub Uddin and A. Raj Chowdhury write: "nanotechnology education should be integrated into mainstream undergraduate [engineering and other related bioscience] curricula" (Uddin and Chowdhury, 2010).

THEORETICAL FRAMEWORKS OF THE MODELING OF SPECIALIST'S PROFILE

Nanotechnology development can be feasible in cases where efficient groups with large proportion of scientists, highly-skilled technical workers engaged in research, design and manufacturing are involved. That is precisely why NTE becomes necessary in order to achieve the growing needs of development. However, there is no clear understanding of which skills and what knowledge and competencies are key for educational process in order to ensure nanotechnological activity in future.

On the whole, NTE of specialists in nanotechnology should be focused on the formation and development of:

- Skills to develop originalinnovative products with understanding of their qualitative advantages
- Representation of market needs by creating innovations with a focus oninternational demand

In addition, future specialists should:

- Aware of social, ecological and potential negative consequences of introduction and application of nanotechnology
- Be able to make an informed choice of optimal ways of problem-solving with constructive and technological usage of already developed innovations

More certain requirements of post-graduate levels of NTE come from scientific activity within scholar schools that can be structured in main characterizations of future specialist by utilising the modeling of specialist's profile. So, NTE with orientation on emerging prospects of nanotechnology development in Kazakhstan is closely linked with forming of professionally meaningful characteristics and traits of future specialists. These characteristics are usually aligned to employers' requirements or in our case by requirements from scientists of scholar schools.

The formation of all appropriate competencies which are dictated by the requirements from scholar schools is realized with orientating on the model of future specialist. Due to the model, it is possible to achieve certain goals for all subjects of educational process (students, teachers, scientific executives).

The model considers a professionally and socially recognized profile of a specialist for specific professional activity and presents ideal, final result of educational process, suitable for a specific professional environment. The achievement of the result gives society a specialist with necessary skills for scientific and technical progress (Levkov and Figovsky, 2011).

Utilizing the model is aimed to getting the needed professional competencies to engage with nanotech development and innovations. Without such model it would be difficult to organize NTE as a real project of NT activity.

As is known, competency-based training is considered as leading in European educational space and there are numerous publications in regards to it. The article "Competencies in use and exploitation: a proposed research methodology" (Harpan and Draghici, 2014), presented methodology comparing employers' professional competencies development with competencies gained during students' education (developed curricula programs in universities) that provide specific qualification. A key element of the above is to coordinate curricula programs with the requirements set by employers. However, it is not always possible to establish a direct link between labor market and education sphere (as in the case of underdeveloped NT market in Kazakhstan). As such, there is a need to use requirements from scientists of advanced scholar schools as employers' professional requirements. Competency-based approach to NTE determines methodology of NTE modeling of a specialist for NT activity. Realization of this model allows ensuring of nanotechnology activity in accordance with real demand of needed personnel.

In order to determine the optimal organization of post-graduate education providing the need for nanotechnology specialists, the theoretical development of specialist's profile was created using next scientific approaches: system, activity and person-oriented.

System-oriented approach has increasing significance among general scientific principles of cognition. Researchers utilize this approach whenever it is needed to synthesize knowledge and get a holistic picture of the phenomenon or process. System-oriented approach serves as the link between philosophical methodology and the concrete sciences (Antonov, 2004; Asmolov, 1998). The use of system-oriented approach allows:

- Structuring the set of qualifications of nanotech specialist with managing of knowledge from different scientific fields during preparation
- Establishing links between characteristics of specialist, professional activity and educational process
- Taking into account innovations and state needs with subsequent coordination of educational programmes
- System-oriented approach enables
- Fullconsideration of benefits of international experience and the most urgent characteristics of specialists
- Modeling, looking at both the holistic picture and all internal links

According to the activity-oriented approach, the activity is considered as dynamic, self-developing and hierarchical system of interaction between a person and the world. As a result, transformation and embodiment of the person occurs in subject reality. Alongside, the transformation of the person-the system is also developed (ex., professional sphere in which the person is active element). Usually, the person in his/her profession faces three aspects of the activity (Chmel, 1998): psychological, theoretical and practical. Therefore, readiness for any kind of professional activity is based on a combination of motivation, content and procedural components. To generalize these components of activity we have added evaluative component that is associated with reflecting the activity and manifested in analytical and corrective actions based on development of the system of values of personality.

Person-oriented approach to the development of model profile of a specialist is closely linked with motives and needs of the individual which determine his/her professional activity in nanotechnology because "the process of reproduction of knowledge and skills can not be divorced from the process of identity formation" (Levkov and Figovsky, 2010). There are some concepts of personal development (Maslow, 1996; Asmolov, 1998) where mechanisms of the formation of a person's qualities are determined by motivations, purposes and conditions of action of the person (Zinchenko, 2002). Some of these concepts have been experimental tested and showed positive results in person's development. The productive ideas of these concepts are used for competency-based modeling of specialist's profile for NT.

Table 1: Structural components of specialist for science-intensive industry (specifically "Nanomaterials and Nanotechnology")

Structural components	Characterization
Motivation	The attitude to scientific and technological activities, the desire to carry out scientific research to master new technologies while the solving of professional problems. The desire to improve, change own submissions in accordance with the latest achievements in professional and related fields
Content	Understanding of the methodology, theory and research practice. Free command of the thesaurus of special concepts as the foundation of professional activity. The assimilation of subject knowledge of the science. Developing of originalinnovative products with understanding of their qualitative advantages. Knowledge ofmarket needs of created innovation with focus on international demand. Awareness of the innovative nature of nanotechnology, social, environmental and possible negative consequences of the introduction and use of innovative products. The study and assimilation of achievements of domestic andforeign scienceand technology with orientation onprogressiveworld experience and perspectives of industry development
Procedural	Wide application of modern research methods in solving of technical problems, design and production of high-tech products. Practical use of advanced scientific equipment and instruments, techniques and technology. Organizing ofindependent research. Using progressive foreign experience. Using the methodology of management of complex objects, systems and complexes. Evaluating ofinnovations and implementation of innovative solutions. Choosing of optimal solutions of problems and constructive and technological ways of introduction of innovations
Evaluative	Mastering of skills ofperception, understanding, assessment, self-esteem,self-control,self-awareness, self-developmentwith maximal use of own intellectual potential. Usage of network, technical and other resources (additional literature and a variety of new sources of information by theme). Understanding of the specifics and features of high-tech products in given field. Getting of successful results in R&D

So, based on above and taking into account the specifics of nanotechnological activity in Kazakhstan, we have developed the structural components of the model of a future specialist in nanotechnology as presented in Table 1. It includes: motivation component, determined by the following factors: valuable relation to scientific and technical achievements in particular area; interest in chosen specialty; analytical abilities; the endeavor to try new methods of research and experiment; understanding of scientific goals and objectives; desire to solve problems of production using scientific methods; aspiration of mastering new technologies and professional positions; motivation related to the need of the person to be in demand and to have growth prospects. The fact of existence of needs serves as a driving factor in the development of personality. One of the most important needs is professional motivation a desire to improve, change own submissions in accordance with the latest achievements in professional and related fields. Professional motivation can be divided into private and common types. Common professional motivation is influenced by environmental factors. Social prestige of the profession has a great importance which in turn, expresses the needs of society and the role that society allocates to that activity. Private motivation is focused on the solving of specific problems or task and connected with various reasons and circumstances. These reasons may have productive, social, personal or educational nature. Private motivation is the basis of different methods of teaching. Education on Postgraduate and Ph.D levels implies high motivation and conscious desire to be awarded degree when a student has already accumulated sufficient basic knowledge and skills, gained some experience in individual subject areas and clearly defined professional scope for himself/herself. Big motivation in the learning can appear only through creative development of domain knowledge and taking on problems of practical importance.

Content component characterizes the assimilation of subject knowledge as a means of solving of professional problems, awareness of their role in the development of professional skills including research methods and system of professional knowledge as the basis of future activity. This component also includes the application of knowledge and the endeavor to model technology processes, predicting their realization.

Content component of activity of highly qualified professionals in knowledge-intensive industries involves developing innovative products with the understanding of qualitative benefits and market demand for innovations and international level.

Procedural component means the mastering of special skills and technologies for implementation of scientific and industrial problems and application of modern methods of analysis and research, development of new ways of problem-solving. Procedural component of activity also involves the perception of progressive experience. In this regard, knowledge of foreign languages for international cooperation and implementation of competitive scientific developments at international level becomes an important skill.

Evaluative component of a specialist in a science-intensive sphere including nanotechnology is generalizing of all previous structural components of specialist (motivation, content, procedural). It should be noted that almost all structural components include:

An innovative aspect, associated with obtaining of new results. This kind of activity requires innovative qualities of specialist's personality based on an understanding of why innovation will be needed, how to satisfy the market what the effect of introduction of innovation in technological, economic, social sphere will be in foreseeable future

The aspect of activity associated with the development of international relations that implies correlation of own experience with world practice. It requires a certain level of core competencies and concentration of the forces on industrial trends integrated into the world community in order to act on international level

Thus, modeling of a specialist's profile is based on elaboration of structural components that determines the nature of productive professional activity in generalized form. Structural characterizations, expressed in competence form during the preparation of appropriate specialist can be extended and modified in different cases of the training.

On the whole, this model presents the basis of educational organization in generalized form which can be used as professional orientation at certain stage of NT development.

In unity of nanotechnology specialists' structural components-competence forms through expansion of functions. For example, we present below a competency-based educational program "Nanomaterials and nanotechnologies" for postgraduates oriented on structural components of specialist's model.

COMPETENCY-BASED NTE ORIENTED ON OPERATING SCHOLAR SCHOOLS

First of all, promising areas of research and development were identified in frameworks of innovative projects implemented by leading scientists at KazNTU in order to realize purposeful NTE oriented on concrete results expressed in competencies. All of research was implemented on the basis of existing or newly created laboratories of the University, using unique research equipment (instruments, installations, measurement systems, etc.). Achievements of the research and development were in demand and interest of various companies both domestic and foreign. Aside from that state support was guaranteed in this area of research in accordance with government programs' of economic development.

Reliance on real research allowed providing reasonable process of training and research work and forming and updating curricula for postgraduates (masters and Ph.D students) in NT field. Consequently, become possible to use scientific, informational, organizational resources, introduce concrete results of research by priority areas into the learning process and ensure motivation, content, procedural and evaluative components of specialist's model.

So, the presence of scientific schools in NT field as a priority area is the main condition for NTE. Introduction of updated courses of academic disciplines in line with real scientific trends is focused on acquisition of certain skills according to characterizations of structural components of the model.

It is important to note that educational program on NT oriented on real researches, meets the principles of consistency and efficiency in general to ensure the integrity of education in this area of preparation.

NT curricula linked with real research was based on modular structure where each module aimed on the forming of certain competencies. During the formation of necessary competencies by modular learning technologies, structural components of the model meet professional requirements from the researcher as main employer of NT sphere in current conditions of NT development in Kazakhstan. Thus, NTE is connecting with real scientific and technical problems in given area that solved in the course of research and development within the frameworks of scholar schools.

Research areas of scientific schools at KazNTU serving as the base of NTE are the following:

- Synthesis of nanostructured carbon materials (Scholar School of prof. D. Smagulov)
- Nanoelectronics and methods of analysis and diagnostics of NM (prof. E. Kumekov)
- Nano chemistry (prof. S. Aidarova)
- Sructural nanomaterials: development of nanocomposites for use in constructions (prof. S. Mashekov)

Corresponding disciplines and modules for learning are focused on certain goals and objectives of relevant field of the study which eventually oriented on structural components of specialist's model (Table 2).

The projection of this research area on educational process has led to design of the content of a variety of disciplines including individual modules aimed on the formation of specific professional competencies (Table 3).

Another example of organization of NTE is connected with nanoelectronicsas one of the most important areas of nanotechnological activity where is the possibility of breakthrough in Kazakhstan. This is due to the needs of miniaturisation of electronic components that form the basis of information and computer technology. The development of this research area can lay the proper scientific basis for development of appropriate educational infrastructure that is needed for achieving of training objectives of competitive specialists in nanotech.

Table 2: Disciplines and modules for learning for relevant area of research and development

Area of research and development	Goals and objectives of relevant field of study	The content of training (disciplines,modules for learning)
Synthesis of nanostructured carbon materials (Scholar School of prof. D. Smagulov)	Getting in-depth knowledge of physical, chemical and physico-chemical processes and also methods, techniques and tools for producing of carbon nanostructured materials in order to make research and developments at modern level	Discipline: "The perspective carbon-based nanomaterials". Modules of discipline: Carbon nanotubes, Polycrystalline diamond,Graphene,Fullerene,Metal-carbon nano composites, Application of carbon nanomaterials. Discipline: "Methods of carbon nanomaterials synthesis". Modules of discipline: Chemical Vapor Deposition (CVD), Electric arc sputtering of graphite, Plasma-Chemical Deposition (PECVD), Discipline: "Modeling of NT processes"

Table 3: Professional competencies forming during the learning disciplines and modules

Disciplines	Modules	Goals and objectives of learning	Professional competencies to be formed
The perspective carbon-based nanomaterials	Carbon Nanotubes (CNT) Appliation of carbon nanomaterials	Study the structure and properties of CNT, methods of growing and application	Ability to work on the laboratory equipment on the base of obtained knowledge
	Polycrystalline Diamond (PCD)	Study the unique properties and structure of PCD, methods of production and usage	Ability to use obtained knowledge in the research of properties
	Graphene	Study graphene properties as prospective material for micro and nanoelectronics, methods of its obtaining	Ability to use obtained knowledge in the development of methods of graphenes obtaining
	Fullerene	Study the features of carbon bond, functional purpose, application	Ability to use obtained knowledge in comparative analysis of carbon NM
	Metal-Carbon Nano Composites (MCNC)	Study physical and chemical properties of MCNC, their carbon matrix, the nature of phase interaction	Ability to use obtained knowledge in comparative analysis of carbon NM
	Application of carbon nanomaterials	Study the prospects for the use of carbon NM as a basis of stabilizers and preservatives in electronics and robotics	Ability to analyze the application from the position of efficiency of properties
Methods of carbon nanomaterials synthesis	Chemical Vapor Deposition (CVD)	Learning the mechanisms of chemical reactions of solid phase deposition involving gaseous compounds (CVD-process)	Ability to use theoretical knowledge in the work with CVD-reactor
	Electric arc sputtering of graphite	Mastering the technology of electric arc sputtering and ultrasonic dispersion for components separation	Ability to use theoretical knowledge of mechanisms of fullerene structure formation from the plazma
	Plasma-Chemical Deposition (PECVD)	Learning basic chemical laws, kinetics and plasma physics,types of discharges used in plasma chemistry	Ability to use theoretical knowledge of plazma-chemical technology for actual application
Modeling of NT processes		Mastering mathematical algorithm of modeling of time-dependent processes of synthesis of CNT	Ability to analyze the features of CNT and use methods of mathematical modeling

Since in Kazakhstan nanoelectronics is a young research area that appeared as a result of the development of solid-state physics, physics of semiconductors and dielectrics, microelectronics which have then determined the selection of new disciplines for this area of preparation: "Nanotechnology in Electronics", "Microelectronics and Solid State Electronics" (Table 4). International experience plays an important role in this area of training making necessary learning of nanodiagnostics, nanoengineering of nanomaterials.

At KazNTU important scientific direction is nanochemistrythat develops in studies by regulation of properties of disperse systems and surface phenomena (Bekturganova *et al*., 2010). Problem of stability of nanodisperse systems is solved on the basis of systematic studies of surfactants, polymers and mixtures. The successful development of this area of research allows to concentrate on studies with subsequent projection on educational process. That is why disciplines and modules given in Table 5 were included into educational program of "Nanomaterials and Nanotechnology (for chemical industry)". They are focused on concrete professional competences, namely:

- Understanding of the behavior of nano chemical components and the ability to predict their stability and physical-chemical properties
- Understanding and ability to solve the problems of stability of nano dispersed systems

Table 4: Disciplines and modules for learning for relevant area of research and development of physical process

Areas of research and development	Goals and objectives of relevant field of study	The content of training (disciplines, modules for learning)
Nano electronics and methods of analysis and diagnostics of NM (Scholar School of prof. E. Kumekov)	Getting knowledge of physical processes in nanosystems; studying element base of nanoelectronics and components of microsystem technique in order to use special methods of analysis and diagnose of NM	Discipline: "Nanotechnology in nanoelectronics" Modules of discipline: lement base of nanoelectronics, nanosensors. Discipline: "Microelectronics and solid state electronics" Modules of discipline: Microelectronics and microsystem technology , Optoelectronics, Diagnostics of integral microsystem. Discipline: "Special methods of analysis and diagnose of NM". Modules of discipline: Methods of transmission and scanning electron microscopy, methods of probe tunneling and atomic force spectroscopy, nanolithography, methods of diagnosis of semiconductors

Table 5: Disciplines and modules for learning for relevant area of research and development of nano-chemistry

Areas of research and development	Goals and objectives of relevant field of study	The content of training (disciplines, modules for learning)
Nano chemistry (Scholar school of prof. S. Aidarova)	Understanding the problems of nanochemistry, the prospects of development in order to have an idea of how to produce new functional nano materials knowing their structure and properties and being able to predict the physical and chemical properties through the synthesis of the knowledge gained in the course of general, inorganic, physical and analytical chemistry	Discipline: "Physical chemistry of nanostructured materials" Modules of discipline: Nanochemical components, Mechanisms of nanosized chemical effects. Discipline: "Colloidal nanochemistry". Modules of discipline: Nanochemistry of disperse system and surface, Phenomena. Discipline: "Polymer nanomaterials". Modules of discipline: The principles of functioning and applying of polymer nanomaterials

Table 6: Disciplines and module for learning of formation of scientfic thinking

Areas of research and development	Goals and objectives of relevant field of study	The content of training (disciplines, modules for learning)
Structural nanomaterials: Development of nanocomposites for use in constructions (Scholar School of prof. S. Mashekov)	Forrmation of scientific thinking of specialists having knowledge in nano-composite structural materials; mastering of skills for application theoretical, experimental and computational methods to solve practical problems of nano-composite materials technology, the creation of structural nanomaterials	Discipline: "Nanodisperse powders" Modules of discipline: Equipment for the formation of nanosied materials, Peculiarities of nanoscale structures

- Ability to apply polymeric nanomaterials knowledge in specific fields of research and development

Active works are carried out in the field of structural research of nanomaterials, therefore, the focus was on relevant research and developments with introducing research works in learning process. Extensive studies in this promising direction are conducted in many countries. To date disperse-reinforced composite materials based on aluminum alloys have been the most widespread. Such materials can be obtained by mechanical alloying (processing of powder in mechanical activator and subsequent consolidation). In this direction, the research of the formation of bulk ultrafine (nano) materials and surface modification of materials are actively developed in Kazakhstan. Accordingly, it is reflected in educational program through including the course "Nanodispersed powders" and modules "Equipment for the formation of nanosized materials," "Peculiarities of nanoscale structures" (Table 6).

Successful development of promising scientific areas promotes not only competitive market of nanoproducts but at the same time, purposefully provides the quality of postgraduates who can effectively carry out activity in nanotechnological sector.

So in fact, educational process adapts to specific activities and real problems of NT development. Competency-based technologies of the training are most effective for planned educational outcomes (specific knowledge, research and professional skills).

APPLICATION OF THE MODEL IN NTE

The overall result of NTE is to achieve such educational level of learners that provides effective professional activity of future specialists in nanotechnology. The content and requirements of professional activity in nanotech is defined on the basis of performing research and development carried out within scholar schools. In given conditions of development, when nanotechnological market is not fully formed, it is rather difficult to choose any other way for determination of professional requirements as educational reference points.

As mentioned, the person in profession faces three aspects of the activity, so structural components of the model were divided by different professionally meaningful aspects while acquiring of professional competency in the system of post-graduate education should cover all aspects of professional activity. It is about getting of the

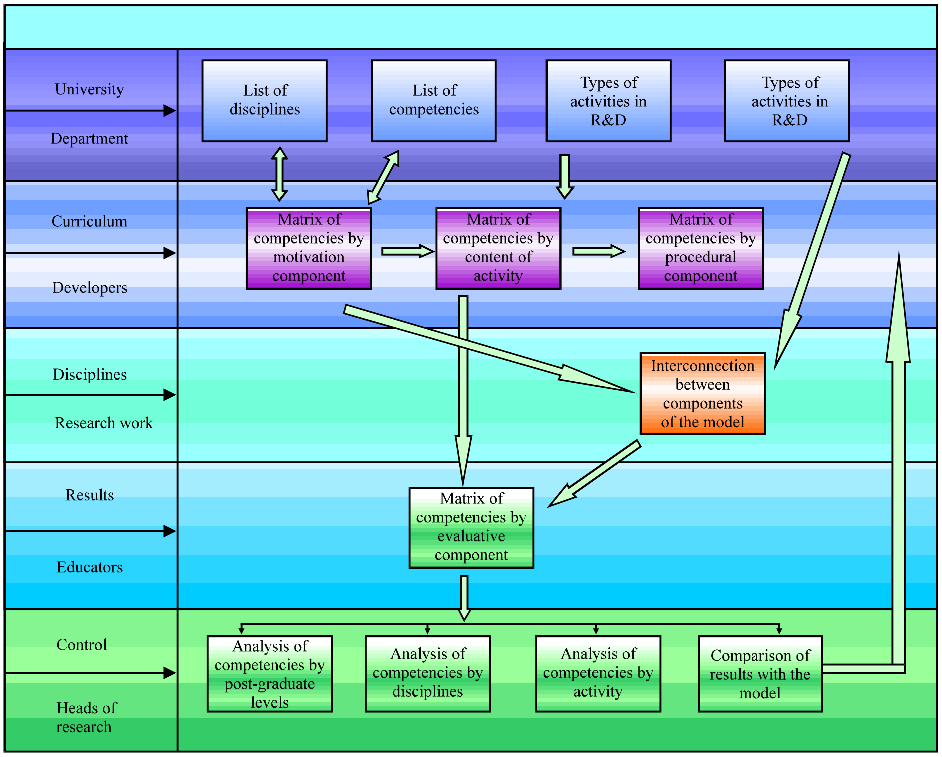

Fig. 1: Logic of application of the model in NTE

aggregate of general professional (invariant) and special professional (variant) competencies in accordance with motivation, content and procedural components of a specialist's model.

Based on the model of NT specialists' profile following competencies are distinguished:

- Those caused by the motivation of future specialists (motivation component, meaning the reflection of the level of claims of learners during NTE)
- Those dictated by the development of nanoscience and nanotechnology, the content of professional activity of future specialists (content component)
- Those connected with procedures during research and development (procedural component)
- Those based on self-assessment and evaluation of professional activity (evaluative component)

All competencies form the matrix of competencies by characterization of structural components which can be applied during organization NTE in various disciplines and different types of activities related to research and development as it is shown in Fig. 1. The first vertical column covers the main objects and subjects of NTE (university, department, curriculum, disciplines, research work, control actions, developers, educators and heads of research). Lists of disciplines and competencies, types of research and developments, control actions are developed at the university (or in the department) form the first horizontal row.

Obviously, there is not possible to form professional competencies according to structural components of the model of postgraduates only during the learning of disciplines, so the types of activity including research and development were considered as the base of realization of NTE. The development of various forms of educational activities related to intensive research work in university laboratories is required in order to solve specific problems. As truly scientific atmosphere arising in the course of studies and solving of large practical problems, creates research spirit and contributes to the development of additional professional competencies, making the model of specialist is more real. That is why, the role of scholar schools is very large as the basis of NTE and at the same time the basis of competence model of future specialists.

All competencies from the model are concretized in matrix that is the complex characterizations of future specialist needed for the performance of professional duties. The matrix allows changing flexibly of all needed competencies under the transformation of activity conditions through standardization and coding of competencies. Matrix of competencies correlates with modules of the curriculum and aggregate of matrixes defines the needed educational result.

Matrix of competencies by evaluative component is formed on the basis of obtained results of learning and intended for assessment of forming competencies through control actions like testing, control work, exams and defense of the diploma. The content of evaluative component in accordance to the model (Table 1) is described by educators during the development of disciplines and research works. For the analysis of learning outcomes usually is used credit technology for assessments of each control: current, mid-term and final. If there is proper assessment of the proportion of relevant competency, then it is possible to get a profile of the student in accordance with the competency model (Mustafina, 2010). In general, assessment of future specialist is realized by such criteria as scientific knowledge, theoretical and applied significance of scientific papers.

Interconnection between structural components of the model is monitored by disciplines and research work in order to design educational results by levels of the preparation. That ensures continuity and succession in preparation of postgraduates and Ph.D according to periods of education. It is important stage of realization of NTE oriented on competency model of future, specialists because educational aims are associated with professionally meaningful competencies on the basis of disciplinary and interdisciplinary requirements.

Analysis of competencies (the last horizontal row in Fig. 1) by post-graduate levels (master or Ph.D students), disciplines and research activity allows comparison of obtained results with the offered model of specialists in nanotech for further improvement of NTE.

Thus, orientation of NTE on research directions developed in the framework of innovative projects of scientists of KazNTU allowed achieving given characterizations of competency-based model of specialists and provide real link between science and education through addressing specific challenges of the industry. Advantages of such organization of NTE can be listed as follows:

- Learning of theoretical material on real problems of development
- Efficient use of complex and expensive scientific equipment (e.g., installation for the synthesis of carbon-based nanomaterials)
- Achieving and assessment of training results by the orientation on structural components of specialist's model

Talking about the possibilities of effective application of competency-based model for teaching in conjunction with real research and promising development, it should be emphasized:

- Updated educational programs for postgraduates in nanotech through expense of elective courses which are variable in different universities of the country
- Increased the number of postgraduates and Ph.D-students in nanotech motivated by real scientific work performed at the university

Since, a number of universities and research centers in Kazakhstan are intensively engaged with nanoobjects the creation of new scientific areas by local scientists is a continuous process which is reflected in educational process of any university as the modeling of specialists's profile is also continuous. So for example, at East-Kazakhstan State Technical University named after D. Serikbayev (EKSTU) extensive research is conducted in nanotechnology and specifically the following areas:

- Natural nanomaterials
- Technologies of extraction of natural carbon nanoparticles
- Nanotechnology for opening of non-ferrous and precious metals
- Nano-films and nano-coatings
- Nanotechnology of obtaining of technical ceramic based compounds of rare metals, etc.

Moreover on the basis of the studies a serial production of technical ceramics was organized. Clearly, NTE at this University is to be adapted to working scholarschools at EKSTU on the basis of own model of the required specialist.

We think our experience of competency modeling of specialist in nanotech is an important part of serious work to develop the justified system of NTE. Moreover, it allows forming individual learning paths through the free choice of disciplines in accordance with the planned objectives and the interests. At this selection, the process of formation of professional competencies is provided with assistance of educators and scientists and it should not be given to students fully. But, it does require a lot of work from those who will ensure familiarity with the content, achievements, prospects of research work both domestically and globally. That is why, the model of future specialist in the given area has increasing role in purposeful preparation of the personnel for nanotechnology activity. Once the student learns about the opportunities and prospects for development of the real state of science and technology in the country and at the university (in comparison with the rest of the world) the proper professional interests and desires can appear that lead to in-depth learning of choosen science and technology.

CONCLUSION

Nanotechnology is considered as one of the priority directions of science and industry in Kazakhstan which ensures diversification of the economy for sustainable development of the country. Scientific advances in the relevant area of knowledge and technology may contribute towards further reorientation of Kazakhstan's economy on innovative development and withdrawal from a raw materials export orientation. The development of nanotech is aimed on providing of technological breakthrough and higher competitiveness of the nation.

As such, there is an urgent need for preparation of competitive, high qualified specialists with a grasp of long-term trends of the industry which are able to engage in large-scale research to solve new challenges of science and production. NTE oriented on emerging prospects in given area in Kazakhstan and is founded on the obtaining of professionally meaningful characteristics of future specialists in nanotechnology that requires determination of basic reference points of purposeful training. So, structural components of the model of specialist's profile were defined on the basis of next scientific approaches: system, activity and person-oriented. In unity of all structural components of nanotechnology specialists (motivation, content, procedural, evaluative) is determined the nature of productive professional activity to be formed through expansion of competency functions. Using of the model is aimed on receiving the needed professional competencies in order to engage in nanotech development and innovations. Without such model it is difficult to organize NTE as real reflection of NT activity. All competencies form the matrix of competencies by characterization of structural component which can be applied during organization NTE in various disciplines and different types of activities related to research and development (Fig. 1).

Significant results within scholar schools of the universities plus orientation on competency-based model of specialist in nanotechnology allow forming learning process at the appropriate level. The presence of scholar schools by priority areas of nanotechnology is regarded as the main condition for NTE. Introduction of updated courses of academic disciplines in line with real scientific trends is focused on acquisition of certain skills according to characterizations of structural components of the model.

So, educational process adapts to specific activities and the real problems of NT development. Scientific results by priority areas of research conducted at KazNTU have served as the basis of upgrading of educational program for postgraduate and Ph.D students. In other words, current directions of Kazakhstan's nanoscience determine the directions of NTE which adapts to certain activity and major challenges of NT. Competency-based technologies of the training are the most effective for planned educational outcomes (specific knowledge, research and professional skills).

Thus, agreeing with the statement that "the strategy of nanotechnology development can only be built on concrete material" a methodologically substantiated model of specialist in nanotechnology allowing to provide purposeful NTE was based on "concrete materials".

Thereby, the experience of NTE with the use of achievements of Kazakhstan's scholar schools and elaboration of competency-based model of a future specialist was presented in the study in context of the development of engineering education.

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