CREATIVITY SHAPING IN ENGINEERING EDUCATION TRAINING

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The article considers a complex problem of creativity training in engineering education. Creativity of engineers is based on the overcoming of "immaturity". There are analyzed proposals suggested in V. I. Livshits's paper on the problem of creativity shaping in the course of engineer training an engineer. It is specified that it is necessary to optimally combine fundamental and professional training rather than substituting fundamentalization of engineering education for professionalization.

Key words: *competence, epistemologist, erudite, system design engineer.*

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Problem situation.

The rushing growth and over-complication of techno-sphere and info-sphere further the development of a new entrance criteria matrix for engineers working in hi-tech, info-tech and science-tech areas. The cooperation personnel departments widely use different methods in evaluating the creativity level of this or that applicant.

As in many cases, the production requirements in techno-sphere have forestalled today's Engineering Education (EE). Currently, the practical aspects of the EE functioning system and its modules are beyond the problems of creativity learning. Numerous institutions, faculties and departments are overcoming the Educational Gap (EG) – lagging from today's reality and EE and yesterday's innovations in the techno-sphere. Employers have coined this phenomenon as EE crisis, the results of which are graduates – engineers «in-white», i.e. erudites, being unaware, fearing and avoiding any activity in techno-sphere-enterprises. Enterprise workers nicknamed such graduates as an «embryo» engineer.

Periodically, universities have made attempts in overcoming EG. However, all attempts resulted in the swapping of «embryonism» to incompetency of the graduates, i. e according to S.N. Parkinson «rust of civilization» [1]. Incompetency to ignorance has been flourishing like a flower within the sphere of EE. The introduction of international EE (MC EE) [2, 3, 4, 5] is based on the competence approach involving the EE requirement to train graduates with a high level of professional competencies (PC).

Thus, the EE problem domain can be expressed as: through the overcoming of «embryonism» and incompetency to high professional competence and only in this case further the shaping of graduates' professional creativity.

What is the role of creativity within the framework of EE? As a matter of fact, some intellectual-scholars affirm that any technology, including engineering, should develop only convergent thinking; while creativity is oppositely directed, i.e. it is based on divergent thinking contrary to logics.

This concept should be left behind. The problem involves the differences in learning motivations (ambitions, education models-EM) for various student groups. One of the basic EE educology axioms established the following EE targets:

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- EM -1– EE brand to improve the individual social status
- EM -2 – EE training competitive professionals for the labor market
- EM -3 – EE ethic imperative to promote erudition (knowledge) within sciences
- EM -4 – EE selection and training of elite social-ranking leaders and groups.

Every education model (EM) has its own specific education program (EP). Training students from different EMs in one and the same «cauldron» is a widespread mistake.

It is obvious that training «everyday» engineers is not the training of the weaker ones, but it is the EE for those aimed at EM-2, but not EM-3. The fact is that for more than 150 years, undergraduates were and are the basic suppliers of professional engineers for the techno-sphere.

The computer revolution created the illusion that the modern intellectualization of the technological environment sharply diminishes the role of engineers «in -black» and, in its turn, resulted in the swapping of engineers «in-black» to engineers «in-white». The most exalted amateurs formulated this as:» Today's engineers is a group of specialists «in-white» swarming around a computer». But this illusion has vaporized –a technician and an engineer «in-black» continue to be the «heart and motor» of a modern techno-sphere.

Creativity in the shaping of future creators «in-black» should differ fundamentally from the upbringing of those wunderkinds stuck to the PC screen.

The multi-year experience of an engineer – mechanic embraces the seven areas of professional activities (PA) – product engineer, technician, production line manager, commissioning engineer, analytic expert, teacher and system-design engineer-generalist. The shaping of creativity should include a specific feature for each of the above-mentioned PA areas.

The objective of the first six PA areas (project, distribution, support, provision and prevention) is to provide a long-term stable operational period of one selected segment or element within the techno-sphere. And only one PA area (system-engineer generalist) is involved in the development of the advanced innovation strategies and tactics to provide a balance of interests within «the stability of PA, i.e. adequacy of its innovative breakthrough».

There are two possible engineering stages in the process of practical info-contacts of the engineer with the techno-sphere activities:

A. Designing a virtual project of this or that object, then a description of the item, system or technology from the standpoint of an external individual, i.e. project engineer, the person making decisions and etc. Implementation stage of proposed innovation is exclusively the result of trivial and routine actions without any creativity.

B. Acquisition of modern process design or technology to obtain efficient results within the real techno-sphere and external environmental conditions in overcoming the ins and outs and existing entropic contradictions arising in the implementation process of this or that innovation.

These stated problems are solved through unconventional, experimental, heuristic and creative decisions and actions. Only the law of the end consumer functions, i.e. prosumer- «producer + consumer», all in one.

Both engineering stages should be reflected in EE while shaping creativity, as the PA content in both cases is quite different.

Creativity (creative) is the ability to perceive the world in new ways, to find hidden patterns, to make connections between seemingly unrelated phenomena and to generate solutions.

Technologically, creativity is the perceptive of achieving a target, finding a way out in dead-in situations, exploiting climate through uncongenial and ingenious solutions by unexpected resources and tools. Creativity has a specific feature- its flexibility in approaching strategies and withstanding stereotypes.

Analyzing the problem area in EE (as stated above), we'll examine the overcoming stage of «embryonism» and incompetency. The following problems should be solved at this stage:

a. Decisive learning concept updating in EE- substitution of EE fundamentalization (FEE) for professional EE (PEE) [8]. It should be noted that PEE, injection of concise technological solutions into the theoretical university matrix, has been the Russian education principle, implanted in the 19th century from European (German) EE.

The work [9] can be used as an EE-based innovation pattern example for curriculum of different departments. Today it's not difficult to find education programs (EP) in Natural Science based on the PEE concept principle both in Russia and abroad, which, in its turn, have elapsed through a long-term testing in prestigious universities and received Russian and international accreditation. For example, the brilliant achievements of academician V.S. Pugachev, who modernized the teaching of higher mathematics at Moscow Aviation Institute (now, State University of Aerospace Technologies), were based on four proposed didactic principles [10]. It would be more challenging to develop EP clusters, implementing the PEE concept and receiving international accreditation.

b. Actively processing educational engineering- technological systems, primarily flexible computer-aided design of production and management [11].

Basic engineering packages, software systems used in the techno-sphere, should be selected, avoiding the application of previously tailored curricula. Students supervised by tutorials should be able to master such unfriendly systems.

c. Introducing certification- testing for profession-oriented teachers.

d. Reviewing the student impersonal approach in the organization of learning groups, seminars and student streams. The present «cauldron» approach unites in one and the same auditorium both «in-black» and «in-white» engineers, professionals and erudites, future production managers and researchers.

If you look through today's windows you can see the XXIst century – a century of single-item (limited) production, target-focused customer services, and unhesitating conversion from «building (convection) to «boutique.» The EE system should also transform, involving such well-known reformation methods as for example, intensive target-oriented professional training (ITPT). Group teaching and student streams should gradually disappear, being replaced by individual (tutorial) teaching.

e. Sequence of education disciplines can be compared to a «Screwdriver factory», i.e. machine assembly line – loose parts are manufactured, units, blocks and separate mechanisms are assembled, then the whole machine itself.

This analog can be relevant to the development of skills and abilities throughout the Natural Science cycle: units – skills obtained in the engineering and professional disciplines and reinforced in term project; the machine itself- graduation paper or project in which everyday engineering problems are being solved. The mental equivalent of this project would be the creation of a graduate engineering thesaurus. This is the so-called Papert principle – constructionism [12] – based simply not on acquiring new skills, but on acquiring new administrative ways to use what one already knows.

In conclusion, it can be stated that implementing the concepts in items a-e would further the minimization of «embryonism» and incompetency.

Experimental knowledge and heuristic solutions play a key role in professional and engineering disciplines (techno-knowledge).

Accordingly, it is essential to boost the engineering training level within the professional competencies as following:

1. engagement of skilled practitioners in key EE problem-solving;

2. knowledge of engineering graphics is a vital tool for any engineer; however the student's knowledge level in this subject is rather low. The reason is very simple-engineering graphics, as other subjects, has been significantly

computerized and has excluded the basic principle of engineering didactics- «The brains are developed by hands»;

3. obligatory propaedeutic courses in professional technology, including practicum based on practical data and material;

4. obligatory internships as an engineering term, where the student perceives the axiom of successful professional activity – « the devil in the details»;

5. development of institutional standards in determining the content of engineering sections in term and graduate papers.

These measures should decrease the EG level in EE. However, resolved elimination of EG is possible only when feedback would be included in the EE module structure, i.e. the index of evaluating the «EE product» by consumer-employer.

The subject of educational activities, i.e. not only the object, but also the subject of engineering learning, is a complex techno-sphere section, in many cases, the engineering-technological system (ETS), through which a person enters the info-sphere to study and attain it for further pragmatistic application. This becomes the bench-mark in determining the problem statement of professional engineering creativity.

In shaping legitimate creativity only accredited and proven knowledge, as a gnostical student mentality model, is used. How this would work is based on the analysis of the two primary postulates in modern epistemology which were formulated by the famous XX-century educator Seymour Papert:

1) One can not be taught – one can only learn. Every person is an (epistemologist) educator by himself.

2) No instructions- only mental constructions- the only tool in learning and teaching [12].

Modern neuropsychology has fully proved the functions of the 2- brain hemispheres. The brain comprised of right and left hemispheres, each of which is responsible for different functions. The right hemisphere controls many of the body's thoughts and actions- intuition, spatial thinking and creative thinking. Inventors have a pronounced left hemisphere, which controls the analytical and logical thinking, organizability and such an important quality as opinionated; i.e. a person of strong principles, obsessed on one's ideas, «finely-honed.» Based on the above-mentioned factors creativity is the result of the thinking function of two hemispheres.

The central chain in EE didactics involves no lectures, no tutorial classes, and no instructions- but only actions, either mental or physical, to complete complicated techno-sphere activities. «To understand one must begin to understand empirically then learn from empiricism to general. To learn how to swim, you need to go into the water» (Lenin).

«Self done is soon done!» Don't wait until something happens, many things can be learned only through different actions and processes but not otherwise.

The up-dated level of the complicated techno-sphere furthered the development of new learning systems based on computer-based simulators, i.e. instructional engineering. During learning a person can generate specific dynamic objects- images. Such temporary objects were considered to be «hybrids» – man + techno-sphere objects and termed as virtual («virtus»- inner). Natural sciences can not explain the energetic activity mechanism linking man with «active» techno-sphere objects. However, the number of recorded facts increased so rapidly like «symbiosis» which is impossible to ignore. In the last 25 years these facts were interpreted and generalized resulting in the emergency of virtualistics – virtual psychology. N.A. Nosov in his monograph wrote: «Virtualistics is not a science, but only an ontological approach which can be applied in any science.»

In psychology and educology virtualistics legitimated the application of a new object-image (virtual) occurring as a result of a person's activity experience. There are two methods in using the simulator or visual object: detached or implanted, i.e. virtual. In the latter case, the image becomes «personal», which rejuvenates the activity itself, making it rather real. If a person finds himself \ herself in a blind alley and continues solving the problem, then the virtual emerges. This develops into creativity-insight, inspiration, understanding, etc., for example: virtuoso-machine operator becomes an integrated part of his machine - tool; driver feels that the vehicle is an organ of his body, even mind; pilot finds out plane possibility frontier and so on. A synthetic specialist manufacturing some products on a unified hardware/ software system and mastering all the details of this operation process becomes its «lord» – creator. It can be stated that virtuals are very common in engineering. Systematology [17] promotes the virtual approach for complex systems in techno-sphere and info-sphere.

Proponents of the EEF (engineering education fundamentalization) are convinced that the shaping of engineer creativity and the cultivating of future creative researchers are synonyms. This is a deception: teaching creativity within EE is considering the examination of heuristic solutions, the core of which is the synthesis system and their acquisition. In engineering, creativity involves the development of new contradiction methods and tools to overcome the «attacks» of engineering solutions. Excluding these facts, humanitarian-erudites suggest using didactics, as a major tool in shaping creativity within EE methodology background of Soviet physics-mathematics school (PMS).

Many didactic scholars introduce PMS methodology as an example-pattern in avoiding teaching through ready-made algorithms and standard problems which they termed as «ill-provided teaching».

According to these theorists, creativity develops only under the conditions of non-standard sophisticated problems. However, in many cases, such problems are purely theoretical or even scholastic ones and not connected with the student's future profession. Academician L.D. Landau stated «the brevity of life does not allow us to enjoy the luxury of spending time on problems which lead us to no results!»

Technology transfer to the «creativity level» is the dark-side of our brains, invisible to both students and teachers simultaneously. There is no proof that non-standard problem solutions could spur creativity and, visa versa, standard problem solutions could not. There is surpassing evidence that rejects the above-mentioned statements. For example, TIPS / TRIZ (theory of inventive problem solving) developed by Genrich Altshuller. Following Altshuller's insight, the theory developed on a foundation of extensive research covering hundreds of thousands of inventions across many different fields to produce a theory which defines generalized patterns in the nature of inventive solutions and the distinguishing characteristics of the problems that these inventions have overcome.

Psychology reveals the most complicated processes hidden under the mask of traditional didactics. The most important characteristic feature of presenting standard and conventional algorithms and solutions is the fact that these samples are models of elegant solutions in overcoming dead-end situations and dead problems. .

This is also an example of implementing the principle of knowledge- technology change-over. Critics of traditional didactics distinguish that cognitive teaching aspect is «ready-made algorithms.» But there is a B-side, i.e. emotive (affective) aspect which is also significant in the teaching result process. It is this aspect that boosts the classical elegant standard solutions in teaching.

It is obvious that comprehending classical solutions has become the backbone and stepping – stone in shaping creativity. Very often, classical solutions can not be formalized and their description is only verbal and illustration and reproduction - only visual. In EE solving standard problems is not teaching stereotypes, but it is teaching standards. Teaching professionals on the basis of previous elegant classical solution thesaurus has been and will be the founda-

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tion of shaping creativity in EE. Studying methods and tools to overcome the past contradictions and barriers results in the development of personal tools and creativity pattern-models.

Fundamentalists interpret «the ability to think» as the ability to make correct problem solutions. However, as mentioned above, according to the professional approach, the problem-solving decision is only the first step in shaping engineer creativity, as the next step involves the implementation of the solution itself in response to the entropic contradictions of techno-sphere and eco-sphere. It is the engineer's creativity that embraces the ability to overcome these contradictions, otherwise, there will be a zero result: «We wished our best, you know the rest.»

The characteristic features of creativity – particularization and professionalism- are applicable to the profession of production engineer, which, in its turn, is subdivided into seven areas.

1. Product engineer – CAD/CAM system engineering showed that the articulation and specification of item (part) production problems in several technological spheres, for example, fabrication and instrumentation, can simply be done by computers. In other words, the product engineer activities are more heuristic than that of the technician.

Today CAD/CAM systems only help the product engineer in designing his / her ideas into a model. There are no intellectual expert-type systems by which the product engineer could enter into the global information database or databank to understand where, how and what is vital in solving this or that problem professionally. In the meanwhile, non-traditional design methods are widely applied, in which numerous designing stages of the tangible object are omitted. Product engineers- «agregatists»- use these methods, excluding the preliminary designing stages and tackle the first machine sample through the «trial-and-error» method by using makeshift means, i.e. time-expired or dead parts, units and blocks. Such actions can be explained if you take a look at the Latin word «construction» which literally means «building, composing». Hundreds and hundreds of successful solutions have been found by «agregatists». It's appropriate to remember the following proverb again «Self done is soon done!» That computers have significantly modernized this unconventional design method can be seen in the development of powerful graphic engineering systems of virtual reality (VR). They are used in designing complex machines and machinery systems where concept design, component coupling, nodal testing and total unit assembly are conducted before the implementation of the physical prototype. This concept is termed as Product Lifecycle Management: Virtual Environment, Virtual & Augmented Reality (VE & VR).

As creative engineering thinking still embraces the empiric and heuristic methods, avoiding formalization, the teaching role of mathematics is rather low. In this case the alternative mathematics can be – TIPS (TRIZ), i.e. theory of inventive problem solving including a series of exercises to develop imagination. Genrich Altshuller, the author of TIPS (TRIZ), proved that all techno-sphere objects develop according to one and the same law and revealed a general strategy –« searching compass»[19]. TIPS (TRIZ) spread widely throughout the world and became a powerful tool in initiating creativity. Gradually the theory of TIPS (TRIZ) developed into the theory of intensive thinking (TIT). A methodological teaching process example of TIPS (TRIZ) in EE can be found in the works of B.S. Sergeeva [20].

2. Technician – is an active participant in both A and B stages of the professional engineer activities within the techno-sphere itself. Today segments and elements predominate in the techno-sphere, showing a high functional level of both physical and informative automatization. To define such techno-sphere components the following terms were introduced: EPS- engineering production system; EPS DT (digital technology)

– machinery and instrumentation which are the objects of techno-sphere to transform these production objects, specified by design information (DI) through tools and instruments, defined by technological information (TI). EPS DT is a complex including people, technological machinery, automated storage-retrieval system and control systems.

Today, it is possible to come across the consequence of «computer euphoria» as the ignorance of technological information (TI) in the production of an item. There is only way to develop a professionally competent technological process – automatic engineering information (EI) transmission through technological information (TI). This is an eternal axiom of technology. Namely this is what is implemented in the integrated engineering design scenario: a combination of formalized CAD/CAM processes and the heuristic interference of the technician through an interactive PC transput.

The professional kit of a technician is described in «Mechanical-Engineering Technology.» Accordingly, professional knowledge can be divided into three clusters: (1) scientific; (2) ethical and (3) expert. The technician often applies one of the three clusters in the TI search for heuristic solutions. However, these clusters do not embrace 100% of all thesaurus technological knowledge. A large volume of knowledge in technology algorithmization has been generalized through CAD/CAM systems. In this case, it is advisable to design special courses in technology, including «Algorithmization of geometrical items and technology: general solutions in CAD/CAM systems.»

The so-called Landau studies have widely spread throughout the developed countries in the field of EE [21], which the author himself termed as algo-heuristic teaching theory, whereas it is unknown in Russia. Abroad this theory is applied in the teaching of effective mental activities within the framework of many different spheres. Due to its astonishing success the Landauians called it «Lev Landau miracle.» The introduction of Landau theory into the Russian EE would accelerate the programmed and adaptive learning on the basis of computers and further the shaping of creativity of future engineers.

The most difficult stage for the technician is stage B- engineering production system (EPS). According to V.V. Druzhinin and D.S. Kontorov, N.N. Moiseev and Stafford Beer, EPS can be associated to cybernetic systems (CS). The basic EPS components are «cell»- technology, while the technology nucleus transferring «genetic» burden - information.

Thesaurus block, i.e. environment info-model and the system itself are typical for environment imaging and self- imaging in CS. Thesaurus block is the study problems and EPS development. Learning subjects in EEC – tutor and expert are part of the info-contact with EPS as a technician, mastering it, and then creating a symbiosis, including intellectual system or temporary CS. Temporary CS is the basic instrument in mastering the complex techno-sphere systems.

Education programs (EP) should be ensure the provision of education EPS- a «table microfactory»- at every department [11]. Based on this EPS a student in contact with his or her tutor learns to develop temporary CSs.

The student develops the most important professional competencies (PC) for a future technician in overcoming the contradictions of the techno-sphere, i.e. both physical (contact with the machine tools, facilities, instruments) and informative (info-contact with PC, CAD/CAM systems and CNC controllers).

It should be noted that the described scenario provides the optimal teaching combination of PC simulation and physical production of objects. This is very important in shaping creativity requirements in EE.

3. Production line manager. The engineering area requires additional knowledge, skills and abilities in management, ergonomics and engineering psychology .

Another essential aspect is a long-term internship (so-called «engineer

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term») as production department manager, as well as, including the following sections in the graduation project- economics, ecology, business management and HSE.

It is necessary to study the experience of the leading corporations which have been applying sophisticated software clusters. The most effective are such complexes as «e-Manufacturing for e-Business».

Creativity of production managers involves mainly such an aspect as leadership. In many cases the creative manager selects the conducting method - conscientious authoritarianism, which does not suppress but, visa versa, stimulates creativity in his or her employees.

Progress is not promoted by systems, but by individuals; where systems are simply activity tools of these individuals.

The experience of different leaders should be duplicated. In argument to Peter principle [22], S.N. Parkinson stated [1]:» That the boundary of competency is established once and for ever – nonsense. This is a myth. Our experience says that we live among people different in their astonishing competency.»

4. Commissioning engineer – requires deep knowledge, qualified skills and professional abilities in diagnostics, engineering graphics, engineering systems of virtual reality for database control, testing and application, electrical equipment and electronics, HSE facilities. To require the vital «creativity luggage» in commissioning operations one must work in-situ through «clinical» and teaching methods.

5. Analytic expert – requires versatile training in meteorology, reliability engineering, production quality monitoring, and laboratory methods in research and even in criminal investigation. This engineer should have a high professional level in such aspects as standardization methods and knowledge of international standards, as well as, professional training in patenting, industrial jurisprudence and international laws.

6. System-design engineer-generalist - technological innovations and globalization are the two major dynamic world vectors of the XXI century. The basic job of a system- design engineer-generalist is to develop the strategies and tactics in each stage, as well as, analyzing the process as a whole. Here the engineer develops such qualities as creativity, non-standard approach and «surprise» decisions.

Innovation not only blows up the techno-sphere itself, but also transforms individual's thinking process (mentality). Not every manager is inclined to change and adopt this or that innovation strategy. Here arises the collision with inertial resistance, especially inertial human resources.

Today all project operations are conducted on PC by the system- design engineer-generalist, due to planning production VR system development engineering which uses the following information technology- CAD/CAM/CAE to design virtual workshops and plants, undergoing further testing to technology, production and organization.

7. Teacher of profession disciples – this professional area is not considered in many cases. There is a very simple primitive stereotype: «Any student can become a teacher in professional disciplines as he \she was taught.» .

The first and obligatory requirement for a teacher is have some engineering experience (years in firm/company/profession/business. Another requirement is extended education in engineering pedagogic. In the leading Russian engineering universities there are engineering pedagogic institutes, department or faculties based on the IGIP principles (Ingenieur Gesellschaft fur Internationale Planungsaufgaben) – international engineering education organization.

For more than 50 years IGIP develops the register of professional teachers in engineering pedagogic, having received the «ING – PAED IGIP» (European

/ International Engineering Educator) status.

Teachers of ING – PAEG IGIP status have to be extremely creative. The reason is very simple- he or she has to overcome vast entropic contradictions in his or her professional activities. The EE system models are far from being adjusted to the teaching process perfectionism. There is a tendency of «hoisting» these subdivisions to false homeostasis level. Don't forget the well-known axiom «The harder the teacher, the better the student.» The teacher must always remember to be in the shoes of his or her student. However, teachers forget or even don't want to remember this skill. Why? A teacher has to spend a gigantic amount of time in lesson preparation, in laboratory, in workshops and, of course, at PC. But the most striking target is to arouse the slumbering creativity in the students. One of the most famous mathematicians David Kazhdan (Harvard, USA) stated:» Intuition requires effort. The more the effort, the more the intuition.»

Learning has become a «companion» throughout the life of a person in the XXI century. Engineer-pedagogue should masterfully possess sophisticated technology, software and hardware. In this case tutors, trainers and gurus having PC in using sophisticated technology and techniques in ESP techno-sphere and info-sphere are more vital than the lecturers reading theoretical subjects. It is they who will become the real creative people in one's professional area.

Conclusion

More often than not, in many respective university departments there are professors who are «ivory-towered» in their professional area for more than 15-20 years. They «play the devil with the students.» The change-over of knowledge, skills and abilities and the development of professional competencies should be developed within an atmosphere of perfectionism, but in a dull virtual or virtual imitation of reality.

Thus the main problem –solving of managers in the EE system models is the everyday struggle against entropic «erosion», which is constantly attacking all the components of the university life- beginning with the classrooms, halls, campus and ending with «creeping» tendency towards non-functional education

The shaping of EE graduate professional creativity can be shaped only within an atmosphere of perfectionism.

TERMINOLOGY ABBREVIATIONS

VR– virtual reality
SES –State education standard
DT – digital technology
NS – natural sciences
KSA –knowledge, skills and abilities
EA– engineering area
EI– engineering information
CS – cybernetic system
MAI– Moscow Aviation Institute
IEES – international engineering-education standards
IE – instructional engineering
EP – education program
PA – professional activity
EEP – engineering education professionalism
PC – professional competencies (competency)
EP – education paradigm
EPS – engineering-production system
SBF – specific brain functions
MMS – "man-machine" system
TI –technological information
TP – technological process
TIPS – theory of inventive problem solving
TIT –theory of intense thinking
EEF –engineering education fundamentalization
PMS –physico-mathematical school
CNC –computer numerical control
MMI – man-machine interface
CAD –computer aided design
CAE –computer aided engineering
CAM –computer aided manufacturing
CS –computer sciences
EE –engineering education
EG –educational gap
PC –personal computer

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