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Technique to Estimate the Competence Level of the Integrated Training System Graduates and the Educational Technologies to Increase it

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Some evolutional aspects of the institution currently known as SibSAU are considered as an example to examine changes in the integrated system of the engineer training on the way from planned to market economy. The results of the analysis of labor market requirements to technical high-school alumnae are presented, and the technique to calculate the students' competence level is proposed. Prospects of some pedagogical technologies expected to increase graduates' competency are discussed.

Keywords: sandwich-program; engineers training; professional competence; pedagogical technology

Introduction

Initially the *integrated training system* (IST) emerged as an educational program in countries with stable market economy thanks to the integration of educational process, science and manufacture. In England it became known since 1903 as "*sandwich-program*", and in the USA it was named «cooperative program» in 1906. In the USSR in 1930-ths there were some attempts to introduce this system at high technical schools but it did not receive any significant spread at that time. In 1950-ths the arms race gave a new boost to this process, as a result several versions of the integrated system of training appeared. The most well-known among them was the "*factory – technical college*" system intended to train engineers mainly for the largest soviet military plants (base plants). From then on this system played a significant role in preparing engineers until the USSR disintegrated in 1991.

The «factory – technical college» system was featured by the utmost rapprochement of educational process and industrial activity. Consequently there was a significant reduction of time necessary to form specialists with the knowledge of manufacture, necessary know-how and skills needed for engineering activity at industrial works, and operational experience within a labor collective. At the same time the educational institution took active part in solving current industrial problems, and the base plant on its part could link its infrastructure and leading experts to the process of training, thus allowing its intellectual and material resources for preparation of engineers. There were some other advantages too. Equipment and devices

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available at the base plant were widely used in the educational process, and students had the right to use its scientific and technical libraries. Also, working students got the same social privileges and guarantees as the plant personnel; their period of work was included in their seniority, etc. The «factory – technical college» system also favorably differed from that of a usual high technical school since no expenses were required on the part of an educational institution to carry out students' industrial practice.

1. From planned to market economy

After the USSR disappeared, the attitude to the above mentioned system of training changed. While the planned economy was immersing into chaos the hard times came for all the former soviet high technical schools which were created in due time to provide the planned economy with their graduates and so were connected to it with innumerable links. The planned economy crash also affected the "factory-technical college" system where the educational institution actually represented one big factory shop designed to produce professionals for the base plant. Nevertheless, many base plants not only survived in the economic havoc but also preserved within them the basis for the professional training system and some prospects for its development on new principles. Here the subjective factor played a big role since the personnel carcass determining the policy in these plants till now to a large extent consist of graduates from this system of training. At the same time the continuous shrinking of the planned economy sphere though did not necessarily meant becoming the full-fledged market economy but forced not only single enterprises but high school as a whole to be guided more and more by the first principles incorporated in the IST at the moment of its creation in countries with market economy. Currently the term "integrated system of training" is understood as "the organizational-pedagogical system of students development by professional training programs of various levels and courses that integrally combines theoretical training and evolutionary professional practical activities (engineering-industrial training) in the chosen sphere (the selected specialty) at the base plant" (Hohlov and Osipov, 2000).

The SibSAU history offers a unique illustration to the evolution of this system of training. The factory – technical college (in Russian called "zavod-VTUZ") created in 1960 at the Krasnoyarsk Mechanical-Engineering Works (Nowadays the Federal State Unitary Enterprise Krasmashzavod) had initially been called on to reduce the shortage of higher qualification engineering staff at the regional level. This task basically has been solved, and the emerged zavod-VTUZ practically completely provided one of the largest soviet space-rocket plants with the engineering staff of required specialties. Teaching students at zavod-VTUZ included mainly traditional pedagogical methods which in the past allowed the soviet educational system surpass in many aspects the foreign ones. However there were also features that distinguished zavod-VTUZ from regular soviet technical high schools. First of all, it is necessary to point out the special form of engineering-industrial practice (so-called "working semester") that allowed students to get better acquainted with basic manufacturing works and specialties, to attain more skills in the engineering-industrial activity sphere, and to prove in practice learned theoretical knowledge of general, technical, and main subjects and courses of specialization. The length of their working semester considerably exceeded the duration of student's practice at regular technical high-schools. The total length of students' labor activity at zavod-VTUZ within the working semester framework lasted 2 years and 8 months while their total study time was 5 years and 10 months. All students went through two stages of the engineering-industrial practice at the base plant.

1 – Industrial stage for juniors. At this stage students mastered basic *working* professions in the sphere of their future engineering specialization, got acquainted with the base plant structure, with basics of labor legislation, economy, organization, rights and duties of the working staff, features and diversities of industrial activity at the base plant, participate as workers in all spheres of industrial and public work. At the preliminary of this stage students studied the introduction into their specialty course and got a general acquaintance with the base plant and main faculty. In the main part of the first stage students were linked to workplaces while periodically changing main working professions.

2 – Engineering stage for seniors. At this stage students mastered *technician* and *engineer* professions according to their specialization, apply, prove and fix in practice the knowledge they got during study, participate in all spheres of technical and public work typical for technicians and engineers, and adapted to industrial realities and engineering activity. At the second stage students were trained at nonproductive posts of the base plant departments, bureaus and sites according to their specialization.

Besides their main work at both stages of the engineering-industrial practice students simultaneously attended lectures, studied at seminars and carried out individual tasks. At both stages the engineering-industrial practice was directed towards maintaining the continuity and the right sequence of mastering subtleties of professional work as students passed consecutively through the following chain of occupations: worker's pupil → worker → technician → engineer.

Political and related economic changes when after a long-term chaos the market economy paradigm actually replaced the planned (distributive) paradigm, negatively affected the well-ordered and as a whole successfully functioning factory – technical college system. As one of the obvious disintegrating trends first of all it is necessary to note the steadily decreasing volume of the engineering-industrial practice. Besides, the number of the workplaces prearranged by the base plant for the working semester constantly decreased year after year. As a result little by little the essential difference between the graduates from the factory-technical college system and usual technical high-school graduates actually vanished.

2. Labor market requirements to technical high-school graduates

At the planned economy epoch graduates got job through the planned distribution and had no right to desert their workplace for three years that actually was the time when they were becoming professionals. The planned economy allowed graduates to be under formal or informal trusteeship of leading experts who facilitated them to get professional skills. Now there is no more such practice not only in private-owned and joint-stock companies but at state industry enterprises as well. The modern labor market demands quite another kind of graduates. They must be able to solve professionally and responsibly the problems that are set before them almost at once as they get a job or after a very short period of adaptation. Besides, whatever profound knowledge graduates may possess do not guarantee yet their successful professional work. Moreover, in order to compete successfully at the labor market that's not enough for graduates to have talent of putting acquired knowledge into practice and even have skills of their use. In general it is found out that many traditional pedagogical technologies suitable for the planned economy age are not a good fit to prepare graduates for the labor market now since they were shaped within the frameworks of the different economic formation and were focused to satisfy its specific needs.

Therefore the necessity is obvious to explore new educational approaches. Among them is the *structural-competential* approach (Churlyaeva, 2005). This approach in no way belittles the importance of knowledge, know-how and skills (in Russian znania, umenia, navyki, abbreviated as ZUNs) got during training and highly valued by Russian traditional pedagogical systems. At the same time this approach indicates the prospects for more effective adaptation of graduates to market realities by extending the educational goals' objective base, activating the educational process, etc. Although competential criteria that can estimate the education quality are currently only being introduced into official educational documents, the professional competence is formed anyhow at high school through the education contents. Thus it is already possible to speak about the presence of competence elements however implicitly presented within the framework of existing educational standards and systems, in particular, IST.

Labor market special requirements to the technical college graduates competence basically do not contradict the academic treatment of competence in terms of scholastic categories, and can be stacked into the scheme of splitting the total competence into separate competencies. The problem was to find the common language between the academic understanding of competence and labor market requirements. Such problem has been solved in SibSAU on the basis of carrying out the examination with leading experts from the Scientific-Producing Corporation «Applied Mechanics» (nowadays the Joint-Stock Company "Information Satellite Systems") and Federal State Unitary Enterprise "Krasmashzavod" taking part. SibSAU as former zavod-VTUZ long-established links with the above mentioned two enterprises allowed to bypass many complexities that might arise when carrying out examinations of such sort and to assess the competence needed from graduates when they enter the labor market.

As a result of the analysis of labor market requirements to the graduate competence these requirements were subdivided into three major groups. These three groups concern the estimation of: 1) graduate's *professional level*; 2) graduate's *personal qualities*; 3) graduate's *communicative abilities.* The first group includes the following eight competency constituent: technical knowledge, functional knowledge, attitude to work, initiative, reliability, talent to cooperate, organizing abilities, talent to supervise. As against technical knowledge functional knowledge means knowledge that do not concern technical aspects of work but rather the comprehension of policy, procedures, practice and functional interrelations that significantly affect the general performance of all the organization where the graduate works.

The second group of requirements covers next 14 constituents: intelligence, flexibility, vigor, persistence, self-control, individuality, activity, steadiness, independence, responsibility, adaptability, imperiousness, humor, punctuality. The third group of requirements includes ten constituents: ability to understand, level of common knowledge, ability to perceive new ideas, ability to make fast decisions, readiness to listen to others' opinions, readiness to transfer information, appearance, talent to talk to workers, technical abilities, ability to do the work you supervise. Here only the basic competence constituents that are required by the labor market are mentioned which does not exhaust all their set.

3. Mathematical procedure to calculate the competence level

The complex evaluation of these three groups of competence parameters and the introduction of the *integral competence factor* (Grinberg et al,

2004) allows doing quantitative estimations of a competence level. The calculation starts with the examination by which specially selected experts are offered to range the estimative criteria. After carrying out the expert estimation in each of the three groups several leading competence parameters are found, however to use them as a base to calculate the integral competence factor is possible only after analyzing the relative importance of their interconnection. We solve this problem by computing the matrix of pair correlation between single competence parameters.

After computing the pair correlation matrix the graphs of essential links between competence parameters are constructed and analyzed. As a result of this procedure, for example, at the first stage of consideration it turns out that to estimate the graduate's *professional level* it is sufficient to use not all the initial set of parameters including eight parameters but only *four* parameters, namely, *technical* and *functional knowledge, initiative* and *attitude to work*. Narrowing of the list of parameters leads to changing their relative importance. For example, technical knowledge gets the importance equal to (roughly) 32 %, for functional knowledge it makes 26 %, for initiative – 24 %, and for attitude to work – 19 %.

After the similar procedure performed with 14 parameters describing graduate as a person and included in the *personal qualities* group of factors, also *four* parameters instead of initial 14 remain in the list of competence characteristics. These parameters are: *persistence, responsibility, activity* and *steadiness*. After that the danger of multi-co-linearity caused by the possible presence of close correlation links between the parameters describing the professional and personal graduate qualities is checked, again like at the first stage of consideration the graph of essential links between competence parameters is constructed and analyzed. The same approach including the two above-mentioned steps is used to check interrelations between the parameters that describe graduate's communicative abilities. As a result from the full set of ten initial parameters in the list of parameters again only *four* are left, that is: *technical abilities, level of common knowledge, ability to make fast decisions* and *ability to perceive new ideas*.

Finally after eliminating all insignificant parameters in order to estimate the total graduate's competence level only *seven* basic quasiindependent parameters remain each of which has a certain weight equal to the factor of relative importance multiplied by an expert estimation grade when calculating its contribution to the integral competence factor $K_{int} = K_{prof.\ level} * K_{pers.\ qaul.} * K_{commun\ abil.}$ (Fig. 1).

4. Pedagogical technologies as feasible means to raise the competence level

So, if we try to essentially raise the competence level of technical high school graduates, first of all it is necessary to pay attention to each of its seven essential constituents presented at Fig. 1. To enhance the «technical abilities» constituent is difficult enough; however, we can always make the proper selection among the high school entrants, besides, to some extent develop these abilities during their training. To increase common knowledge does not seem to cause any problem. The level of technical knowledge required by the labor market can be improved by traditional pedagogical methods. In some sense the same is true with responsibility and persistence. The main problems we have to deal with are initiative and especially functional knowledge – the new special labor market requirement to graduates.

Below some pedagogical technologies that were used to shape graduates' competence during the Krasnoyarsk zavod-VTUZ evolution to the

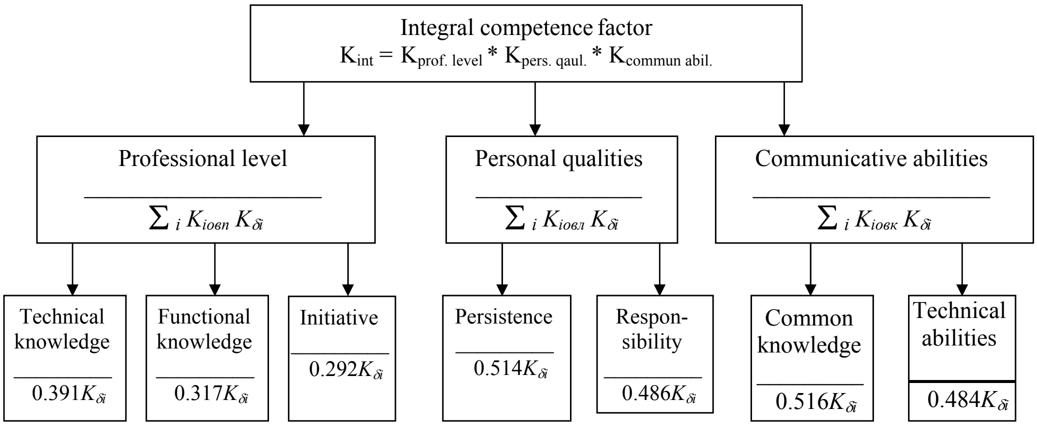

Fig. 1. The basic constituents' contribution to the graduate's integral competence level. Numbers correspond to factors of relative importance, multiplied by an expert estimation grade

institution that is known nowadays as SibSAU are briefly described (Churlyaeva, 2006).

1. The *full learning* technology. This technology arranges the educational process so that to bring each student to a standardized, precisely set level of getting knowledge and skills. Two moments are essential: a) the teacher's general orientation towards that *all* students can and should master completely the teaching material of a given course; b) the development of the full mastering criteria for a course or an issue. This technology is mainly limited to *knowledge* and *perception* in the cognitive area of consciousness, so it does not allow increasing the competence level basing on the teaching features that stress more distinctly such pedagogical goal-aiming categories as *relevance, analysis* and *synthesis.*

2. The *concentrated training* technology (CT). This technology is mainly intended to hinder overlooking the teaching matter that was learned before. The opportunity to concentrate on the subject deeper is provided by combining classes in certain modules and reducing the number of concurrently taught courses. Comparing this technology to the full learning technology applied to the general educational courses module one can see some positive effects since in such module the educational goals both in the cognitive and affective areas are naturally presented even in a truncated form. This technology enables to raise the level of common knowledge, responsibility and persistence. At the same time the lack of stable links between some educational goals in this technology does not allow to achieve a needed level of competence even for the module (truncated) function of competence.

3. The *pedagogical workshops* technology. This technology is designed to individualize essentially training methods. Thus the "workshop" concept included in the training system is pointed out. Unfortunately, a wide use of this technology is limited since it ultimately demands the presence of a high-qualified master-teacher which is rarely possible. In fact it turns out to be the most efficient in a pre-high-school preparation that is carried out, in particular, at the SibSAU lyceum. With this technology one can achieve a big positive effect when teaching technical and functional courses if it is combined with the concentrated training technology. In this case it is possible to alter essentially the general scheme of links between educational goals in the cognitive and affective areas, expanding it as much as possible.

4. The *training as educational research* technology. The necessary precondition to use this

technology is that students must feel dissatisfied with the concepts they possess up to now. Besides, the new concepts that they are going to get should be clear, plausible and potentially congruous with their former ideas while new ideas should help to solve technical problems and promote new theories. The best way this technology showed itself was at seminars in the general educational modules. In view of the competence level increase this technology mainly helps to improve common knowledge, responsibility and persistence. Not much good is to use it at the start of training. At the second year of study this technology starts to yield comprehensible results, and then gradually its efficiency diminishes. Also, this technology leads to a sharp increase of the students independent work time.

5. The *collective brain-activity* (CBA). In the core here is the formation of a problem situations file which is provided with the module system that in a technical college are formed not as interdisciplinary but as intra-disciplinary modules. This technology can be effective to study problem issues that are for the first time considered in educational process, for example, introduced by a high-school academic board. From the competence point of view this technology has rather essential restrictions caused by, first of all, the essential impossibility to achieve fully all the educational goals in the cognitive and affective areas. In this case the general scheme of links between educational goals breaks up so that, in particular, in the cognitive area such goals as “synthesis” and “estimation” become hardly attainable, and in the affective area the same is with «application of progressive technical orientations», etc. Results of examination tests also don’t give evidence in favor of this technology. At the same time if this technology is combined with the CT technology, the truncated educational goal links scheme again extends up to quite a comprehensible one.

6. The *heuristic training* technology like the three above-mentioned ones emphasizes the personal orientation of training. However, in this case the stress is transferred from the question «*to teach what*?» to the question «*to teach how*?» . From this point of view this technology is of interest, first of all, for general educational modules basically promoting the competence level rise through stimulation of initiative and persistence. However, as long as the state educational standards exist with their rigid regulations giving emphasis to «*teach what*» this training technology does not allow to wholly benefiting from its use, especially in technical and functional modules. Experimenting with this technology revealed that under certain conditions, for example, when preparing a diploma, the situation of educational pressure promotes to achieve positive results. Thus approximately 95 % of students successfully manage with their diploma, and only 1.5 % of students do not succeed. In this case the educational goal links scheme in the cognitive and affective areas is very close to the theoretically possible one.

5. Results and Discussion

Analyzing and generalizing the experience of applying these above-mentioned pedagogical technologies to a large variety of technical high-school students, we can draw the following conclusion. Whatever particular positive effect these technologies could have as to developing the so-called ZUNs, none of them allows reaching the competence level required by the labor market because the degree of their influence on all the essential constituents of the integral competence factor is generally limited. The following table testifies to this statement:

From this table one can see that the best results are that of raising common knowledge and the worst are when trying to teach functional knowledge or improve the initiative. In many

Table 1. Pedagogical technology influence on competence constituents as to whether it provides labor market requirements. Symbols: □ – provides good enough, ∇ – provides to a certain extent; ⊗ – does not provide at all

COMPETENCE CONSTITUENT / PEDAGOGICAL TECHNOLOGY	Technical knowledge	Functional knowledge	Initiative	Responsibility	Persistence	Technical abilities	Common knowledge
1. Full learning	∇	⊗	⊗	□	∇	∇	□
2. Concentrated training (CT)	∇	⊗	⊗	□	□	∇	□
3. Pedagogical workshops	∇/ □	∇/ ⊗	∇	∇	∇	□	□
4. Training as educational research	∇	⊗	∇			⊗	
5. Collective brain-activity (KBA)	∇	⊗	⊗	∇	∇	⊗	
6. KBA + CT	∇	⊗	∇	∇	∇	∇	
7. Heuristic (under certain conditions)	□/Δ	∇	∇	∇	∇	∇	∇

respects this is connected with the fact that at a technical high school the goal-aiming specificity in different fields of knowledge causes differences in educational goals in the cognitive and affective areas for common, technical and functional knowledge. For example, in the cognitive area, within the basic pedagogical category "synthesis" the generalized types of educational goals for technical courses include the ability to combine knowledge from different areas in order to solve purely technical problems while for functional courses the same refers to solving technological problems, etc. Also, in the affective area the educational goals categories for technical and functional courses coincide but differ from the educational goals for general educational courses. For example, for technical courses the educational goal «developing progressive technical orientations» includes a firm desire to master a certain scientific and technical direction while for general educational courses it means only learning a certain item of a concrete course section.

6. Conclusion

Taking into account the above-mentioned features, some prospects to increase the total competence level seem to have methods of the educational process activation conjugated with the working process imitation (M. V. Lukyanenko et al, 2005). The most attractive of these methods amount to organizing the educational activity in such a way that it activates a special imitating mechanism of goal-aiming to attain certain educational goals in the cognitive area. As a result of experimenting with senior students groups studying some problem courses it appeared that this imitating mechanism coupled with the network approach can sharply increase the level of functional knowledge sometimes from the value 0.11 in the control group up to the value 0.68 in the trial group, and the level of the initiative from the value 0.1 up to 0.53. Responsibility and persistence grow too in the trial groups compared to control groups. It was found out that the greatest gain in functional knowledge can be provided by methods using business games combined with students' works supported in front of the board of experts. Here the educational process must be organized so that business games make a throughout basis during all the training period. Unfortunately, such process demands special preconditions and is hardly realized within the usual educational activity framework in a technical college with its traditionally rigid lessons schedule and alternating courses.

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Методика оценки уровня компетентности выпускников интегрированной системы обучения и педагогические технологии для его повышения

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На примере рассмотрения некоторых аспектов эволюции высшего учебного заведения, известного в настоящее время как Сибирский государственный аэрокосмический университет, исследуются изменения в интегрированной системе обучения при переходе от плановой экономики к рыночной. Представлены результаты анализа рыночных требований к выпускникам высших технических заведений, предложена методика расчета уровня их компетентности. Обсуждаются перспективы использования некоторых педагогических технологий для повышения компетентности выпускников.

Ключевые слова: инженерное образование, профессиональная компетентность, педагогические технологии.