Journal of Siberian Federal University. Humanities & Social Sciences 7 (2013 6) 1075-1084
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УДК 378.1

The Problems of Engineering Education and Graduates' Development in the Workplace

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Received 04.10.2012, received in revised form 30.04.2013, accepted 05.06.2013

The peculiarities of indigenous engineering education are briefly considered from the historical standpoint. Based on this, the current system of engineering training in higher education institutions is appraised as inadequate and the higher education prospects in the near future as unclear. Better prospects for preparing engineers have continuing professional training systems in industrial corporations. Besides targeted training in higher education, much attention within corporative continuing training is paid at the development of engineers in the workplace. This assumes certain prerequisites such as good organizational climate and big enough learning potential of the workplace.

Keywords: Engineering education, Educational policy, Continuing vocational training, Situated Learning, Learning potential.

Introduction

'The technological achievements of the USSR [were] generally recognized as stemming from their system of education' (Armytage, 1962), so until the USSR collapsed and some time after that 'there [was] increasing interest in the Soviet education system and the changes influencing it following perestroika' (Griffin and Bailey, 1994). Yet, those changes were not for good. Now this system can neither provide the kind of graduates required in industry; nor has it retained the good form it displayed in the past but has been fairly degraded over the last two decades.

Worse yet, created within the matrix of a planned economy, the engineering higher education (HE) system seems hardly reformable. In spite of the long-lasting rhetoric about its 'radical reforming' (e.g. Alekseyev, 1994), in fact, as the President of the Russian Association for Engineering Education admitted not long ago, 'an obsolete system of engineering training… [that]…performs well in totalitarian regimes and was a good fit for the Soviet economy still remains' (Pokholkov, 2010).

The Bologna prescriptions including the two-level HE system, European Credit Transfer

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System, and the competency-based standards are now introduced in HE but this will hardly improve the engineering education quality. D. Medvedev has admitted two years ago: 'division of our education into the masters and bachelors has not yet led to the rising of the engineering education quality, as it was hoped for'. Thus not many good engineers can be expected soon from HE.

Meanwhile, our pedagogical experience allows making an argument in favor of continuing engineering education in innovative businesses rather than in HE alone. In order to better understand the current problems of engineering education and trying to find the solution to the problems, first we have to consider retrospectively how they evolved.

1. Preparing engineers for the planned economy

The Soviet system of *mass engineering training* was designed for the planned economy, so 'HE produced specialists who were expected to progress into corresponding occupations' (Robert et al, 2007). In this way HE institutions prepared specialists for reserved places of duty at industrial plants, fabrics and other organizations in accordance with the needs of those organizations.

HE was supposed to produce engineers who must be ready to build in technological processes immediately after graduation. For this reason every HE institution was affiliated with one or more industrial organizations and in addition to academic lessons, each summer, after the second year of study, each student had to go through *industrial practice* in order to get more closely acquainted with industrial realities. The share of students' practical training and work experience had to be not less than 30% of the total teaching time in a HE institution.

Graduates were assigned to work where as a rule they underwent industrial practices and were sent there as *young specialist* with no right to leave their workplaces for three years. For those 'initial three years of their working lives in occupations and places to which they were directed' (Roberts, 2006), graduates went through a kind of apprenticeship learning under the trusteeship of older/more experienced industry experts.

That was when young specialists were really professionalized. During those three years and more they not just worked but were learning in the workplaces long before *informal learning* became the subject of academic studies (e.g. Eraut, 2004). Absence of private ownership and good social climate encouraged older specialists to share for free their knowledge and skills with novices.

Informal learning in the workplace plus *action learning* (e. g. Revans, 1982) provided a customized training and allowed even poorly educated graduates to develop skills at their workplaces step by step, thus facilitating their subsequent development as engineers.

A high level of secondary education allowed making a good choice among entrants in HE. Thus not very sophisticated traditional educational methods in HE were efficient enough as long as were implemented on fairly advanced students within though authoritarian but well-organized HE institutions. Those traditional methods were quite a good fit to provide planned economy with needed graduates, especially if one bears in mind their further development in the workplace.

The above-mentioned compensated for the many shortcomings of Soviet engineering HE.

2. Integrated training system: a Soviet version of the "cooperative program"

In Soviet engineering education there was one system which included intensive learning in the workplace both before and after graduation, and so was distinguished by the utmost rapprochement of the educational process and industrial activity. This system until now is specified as integrated training system (ITS) originally known since 1906 in the USA as "cooperative programme" (Smollins, 1999). In the USSR, ITS was implemented at giant industrial plants (base plants) which could afford creating special HE institutions to prepare engineers for their own needs.

The most significant feature that distinguished institutions with ITS was *engineering-industrial practice* in the *working semester* alternated with a semester of academic coursework. The length of the working semester considerably exceeded the duration of the industrial practice for students in regular HE institutions. It allowed students get better acquainted with basic industrial works and specialties, attain more skills, and prove in practice academic knowledge.

Other advantages of institutions with ITS compared to regular engineering HE institutions were that a base plant could link its infrastructure and experts to students' training; render its human and material resources for preparing engineers; make the equipment and machinery available for educational purposes, etc. Also, the time necessary for students to know of manufacture, get needed skills and operational experience within a labor collective significantly reduced.

The most successful form of ITS was implemented in such institutions as the Krasnoyarsk Zavod-VTUZ created in 1960 at the Krasnoyarsk Mechanical-Engineering Works (Krasmashzavod) in order to provide one of the largest Soviet military plants with the engineering staff. ITS was developing steadily within Zavod-VTUZ until the USSR disintegrated.

3. Degradation of ITS in the transition to what is called market economy

After the USSR collapsed hard times came for all engineering HE institutions, especially for those with ITS which actually represented one big factory-shop designed to produce engineers for a base plant. Since then the positive development of ITS stopped and its degradation started.

In the HE institution at the 'Krasnoyarsk Mechanical-Engineering Works' ITS was shrinking along with the changes of its names: 'Zavod-VTUZ' (1960-1989) → 'Space machines institute' (1989-1993) → 'Siberian Aerospace Academy' (1993-2001) → 'Siberian State Aerospace University' (2001- nowadays). Each renaming was proclaimed as though symbolizing a new achievement on the road of progress while in fact was only an imitation.

In fact, the state of the rather developed and effectively functioning ITS was only ever worsening. Among obvious destructive trends were the gradually decreasing volume of the engineering-industrial practice and diminishing number of workplaces for students at the base plant. Devaluation of this special form of industrial practice that distinguished zavod-VTUZ gradually made this institution in its main features resemble a regular engineering HE institution. Therefore, now one can hardly even tell about the existence of ITS in SibSAU at all. Having lost all the advantages of an institution with ITS, SibSAU obtained all the drawbacks of a regular current engineering institution.

After the USSR collapsed and chaos started, there was a good side, too, since the control in HE failed and unique opportunities emerged to do pedagogical experiments with other than traditional methods (Kukushkin and Churlyaeva, 2011a). After applying various educational methods (technologies) to a wide diversity of students in hopes of improving education quality and analyzing students' competence with our own technique (Lukyanenko and Churlyaeva, 2010) we drew the conclusion that currently none of these methods allows reaching the competence level required in industry.

4. Devaluation of the entire engineering education

Built within the planned economy matrix and suited for its specific needs, engineering education inevitably had to spoil after the planned economy collapsed. Yet, its current poor state was not so much inevitable but depended on the educational policy within the general strategy. Having chosen the course toward a raw materials economy, Russia was doomed to a raw materials resource for other nations with no serious motivation for engineering education.

When nearly all the industries (except for raw material extraction and export) stagnate or spoil the demand on engineers can only decrease. Consequently, the number of engineering graduates decreases whose share in the total number of HE graduates already drastically reduced from 42% in 1988 to 22% in 2008. Yet, the smaller percentage of engineering graduates did not mean their better quality. On the contrary, the engineering graduates' quality decreases for a numbers of reasons; some of them are mentioned below.

The fail of central planning did not mean a full-fledged market economy emerged, yet indigenous HE institutions allowed themselves to be guided by irrelevant-for-Russia examples from more prosperous countries with market economies. In particular, the much greater independence of universities there encouraged the decentralization of native HE institutions; many of these are still owned by the state though they now bear the label of "universities."

While in some countries which Moscow reformers took as examples to follow 'government attempts to impose [in HE] centrally-defined forms of professionalism' (Lucas and Nasta, 2010), Russian 'Central government decided, in a sense, not to decide, meaning that they decentralised control of public education… and transferred responsibility for decision-making to…young people, local or regional governments…businesses and HE institutions' (Roberts et al, 2007).

In fact, responsibility for decision-making was transferred only to the heads of those HE institutions. Having obtained decision-making power, with actually no more command and control "from above" and no obligations with regard to students, teachers, and other employees "below", these heads happened to hold all the financial and administrative power of their institutions in their hands. The results were discouraging.

Not bothering at all 'how the university's third mission of community service could be integrated more effectively into its other two missions of teaching and research' (Preece, 2010), they were not even worried about the university's first and foremost mission -- the mission of teaching. They made use of their high posts not to start with the problems of re-equipping or improving curricula: 'since 1991 the renewal of [technical] universities' teaching and laboratory equipment practically stopped' (Smolin, 2004).

Instead, they 'extended fee-charging and opened the doors of technical universities wider for economics…banking…law' (Roberts, 2006), and other 'new prestige subjects…[and]…engineers soon ceased to be the typical products of HE' (Roberts et al, 2007). Ostensibly, this was done in order 'to enlarge the budgets of universities' (Meshkova, 1998) but actually because the HE heads themselves just wanted to get a certain percent of the profit from the new activity.

Most teachers, however, got nothing, and many good ones had to leave because of low wages and other reasons. 'Since 1991...more than 300 thousand most qualified scientists and educators left HE institutions, some of them left Russia' (Smolin, 2004). New, often accidental, obedient but not really competent people took their places. In general, the contingent of technical specialty teachers essentially remains at the same level: it has not grown in size, only in years.

Also, the learning ability of students decreased because of new rules for admission in HE, the removal of Soviet concessions for students, and, especially, because of the decreasing level of applicants due to the deterioration of secondary education. This became especially noticeable when the new generations, raised and schooled after the USSR collapsed, started to enter universities.

In hope to improve the situation Moscow reformers try to introduce the Bologna prescriptions aimed at creating a European HE Area with compatible degrees but this will hardly improve education quality. In practice, these so-called reforms will only mean 'final breaking down of Soviet engineering education created within the planned economy matrix and essentially incompatible either with authentic market or what is understood by market in Russia' (Lukyanenko et al, 2012).

5. Continuing professional training versus purely university education

Given the above, industrial employers can not count solely on the existing system of engineering training at universities, especially as regards preparing creative engineers (Kukushkin and Churlyaeva, 2012), and indigenous employers are not alone. Even in technologically most advanced countries university education is much criticized by employers. For example, in the 2006 U.S. Commission on Education report the phrase "business complains" was repeatedly mentioned as regards the poor preparation of engineering graduates (US Dept Report, 2006).

When recently surveyed, about half of more than 1,000 employers in various US industries voiced the opinion that students should receive specific *workplace training* rather than a broad-based education. 'Universities are… giving [students] and what they want, instead of what the employers want,' they also said. According to the survey results, less than 10 % of employers thought HE did an "excellent" job of preparing students for work (US HE Accrediting Council Survey, 2011).

Moreover, even if university education is considered to be good, there's always a certain discrepancy between academic goal-setting in HE and engineering practice in industry. In spite of the many efforts in this area, it has gradually become clear that university education can not replace work-based learning. Thus more attention should be given to the continuing training of engineers with more focusing on their learning in the workplace (Dutta, 2009).

As a result, globally the argument often is made in favor of development of engineers within the systems of *continuing professional training,* especially those systems that exist at enterprises involved in innovative activity. A good albeit rare indigenous example is Information Satellite Systems Joint-Stock Company ((ISS JSC; www.iss-reshetnev.com) where the continuing professional training system emerged within the planned economy framework contributes significantly in improving professional skills of all the personnel including engineers (Kukushkin and Churlyaeva, 2011b).

Here within the concept of a *united educational sphere* students' target training was introduced instead of the former federally-planned preparation and compulsory work allocation. The concept assumes effective functioning of the "School-HE-Company" chain where pre-college training (in affiliated schools, colleges etc), pre-selection of promising students, training target students in HE, and job-specific training engineers in the workplace are interconnected and controlled by the Company.

This chain is an effective substitute for the former centralized preparation and distribution of students. Like before, it assumes the existence of a network of secondary and HE institutions affiliated with the Company and like before secondary schools are the main route into HE. However, since 'the old communist structures that had formerly guided young people through their school-to-work transitions are no longer operative' (Roberts, 2006), now the linked institutions ensure a continuous inflow of labor through the target training.

6. More importance than before for the workplace training

Unfortunately, such advanced corporations as ISS JSC are very few and not much from their experience goes well with many other industrial plants where it is hardly possible to talk about innovations. Also, not many businesses are able to organize their own "School-HE-Company" chain in order to get well-trained engineers. Nevertheless, our experience as well as a similar experience from technologically advanced countries may be useful when technological innovations must be implemented.

Firstly, the experiences show that technological innovation quickly lead to inadequate HE results no matter whether the education is good or bad. Secondly, paradoxically, sometimes the intellectual horizons of well-trained graduates are more limited compared with the less-trained ones. This narrowing of students' intellectual horizons in the process of acquiring of knowledge on specific subjects is identified as *accidental incompetency* (Radcliffe, 2011). It occurs when in the course of teaching technical subjects in HE the broader aspects of education are suppressed or even lost.

Therefore, even if a graduate is poorly educated in HE, in case he/she possesses certain *engineering talent*, there is always a chance to use him/her in industry effectively enough, sometimes even more effectively than a better-educated graduate.

Consequently, more importance than before should be given to the workplace training within continuing training systems in 'a growing belief that the distinction between formal and informal education is unhelpful because it implies the superiority of learning which takes place within educational institutions over, and distinct from, that which occurs in settings such as the workplace' (Fuller and Unwin, 1998). Yet, one should bear in mind that 'the workplace is not a panacea, but just one of the learning environments in which to become competent' (Nijhof and Nieuwenhuis, 2008). Thus, all the other environments and pathways where competencies can grow, including targeted training in HE, with all their possible drawbacks, should be taken into account and the drawbacks minimized.

In order informal training in the workplace to be effective, changes must occur not only in the workplace but in the concept of "workplace" itself. Particularly, apprenticeship in the workplace should be reconceptualised in order 'to reconcile the previously polarized positions of learner-centered and transmission approaches to pedagogy' (Fuller and Unwin, 1998). In this case the workplace can potentially become the place where engineering skills may be developed. Yet, certain prerequisites must be provided beforehand for such a development, and the first and foremost one is the provision of a favorable environment for a particular workplace.

One such favorable learning environment was proposed earlier in *Communities of Practice* defined as 'a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping communities of practice' (Lave and Wenger, 1991). Such an environment is a reminiscent of the planed economy epoch when good social climate of workplaces in industry and many other places, too, was provided largely by the absence of private ownership.

In such an environment effective informal learning or *situated learning* in the workplace is possible, given that there is a big enough learning potential of the workplace.

7. Chances to fulfill situated learning in the workplace

Shifting the focus in the workplace from a learner to a trainer, at the current stage of corporate development of indigenous engineering "apprenticeship" can be reconceptualised in favor of "mentoring". Of course, mentoring now is very different from the one that took place in the Soviet times when favorable environments around young specialists emerged in a natural way.

Firstly, now there is no more former federal distribution to work for graduates who employers had to take care of. Therefore, even if a graduate gets a job, usually there is no his/her further development as a "young specialist". For most businesses there is even no idea of "young specialist" at all, and employers require an immediate return from graduates as soon as they are recruited or after a very short period of adaptation.

People in industry are also not eager to help graduates in the workplace. Surveys show more than 70% of employees are hostile to graduates since they see in them not future colleagues but potential rivals or contenders for their own posts. Only about 15% of surveyed agree to share their knowledge, skills and experience with novices, besides, not for free like before but for a 'good' reward. In the absence of systematic mentoring from more experienced professionals HE graduates usually have to adapt on their own to working conditions, not to mention their development as engineers.

A significant deterioration of morale, social and organizational climate in most industries over the last two decades does not contribute to a favorable environment in the workplace. As for space industry enterprises, in the past creating and maintaining such an environment there was promoted, in addition to good wages, by such important moral and psychological factors as awareness of the importance of their mission, membership in the prestigious industry, pride to be involved in a great state business, etc. To what extent these factors are currently effective is still to be answered.

Without improving morale in the workplace mentoring used for situated learning is impossible and this, in turn, is impossible without implementing the principle of *social partnership.* Focusing on social partnership involves not only the targeted but also the motivational orientation of learning, with the objectives and intentions of individuals inextricably linked with their work and the entire corporate life where the social and individual basics are tightly intertwined. An important role hereby is given to the administrative support of mentoring in the workplace.

Another prerequisite for effective situated learning is a fairly large *learning potential of the workplace* (Nijhof and Nieuwenhuis, 2008). Where there is no *mass production*, not a conveyor but an individual is in the central position as regards production. This in itself contributes to creating a favorable learning environment in the workplace around the individual, of course, in case of the positive development of that production. Thus, for a *singular,* successful production the learning potential of the workplace at all levels -- from ordinary workers up to persons in charge -- is usually big.

A good example is the production at JSC ISS, which for a number of reasons has developed not only as a Research and Production (NPO PM), but also as a *learning* *organization* with all its attributes (Pedler et al, 1992) where working and learning are interconnected processes.

Besides the type of production, the learning potential of the workplace to a large extent depends on the level of production and its material state. In a stable social and economic development the learning potentials of workplaces within most enterprises tend to accumulate over time. In contrast, in the times of social transformations or upheavals such as the hard times of the 1990s, the learning potentials of many workplaces significantly reduce and sometimes even achieve virtually zero.

Nevertheless, if the learning potential of the workplace was not lost completely in the process of destruction of production, there is always an opportunity to restore it again almost to its original state and make use of it in new conditions. Once big enough learning potential of the workplace is restored as well as good moral and organizational climate, it is possible to speak of creating favorable environment for mentoring and graduates' effective development in the workplace.

Conclusion

The Soviet system of *mass engineering training* was built within the planned economy matrix and produced graduates well suited for a planned economy. After the planned economy collapsed, that system started to erode, and now it neither retains the good form it displayed in the past, nor produces graduates who go well with industry requirements.

Worse yet, what we are now witnessing as its fast reformation in practice will mean nothing but its final breaking down. However, breaking down an old system does not mean creating a new one just like the collapse of the Soviet planned economy in 1991 did not mean appearing a full-fledged market economy in Russia.

Thus, in the near future we can expect neither improvement in engineering education nor enough adequate graduates prepared solely in contemporary technical universities.

In 1958, when the 'weakness of [American] engineering education [was]...obvious, many large industrial companies...such as General Electric or Westingaus create their own engineering schools where engineering graduates from HE... are additionally trained in selected areas of engineering' (Timoshenko, 1959).

Now in Russia one, too, can only hope for relatively effective preparation of engineers within corporative systems of continuing professional training at such enterprises as Information Satellite Systems Joint Stock Company. Besides training engineers in the workplace, it includes pre-college and targeted training in affiliated schools, colleges and universities.

Unfortunately, such advanced corporations as ISS JSC are very few, and most industrial plants can not organize a full "School-HE-Company" chain to prepare engineers for their own needs. Yet, some of them can still organize training engineers in the workplace, given that a good morale and organizational climate and big enough learning potential of the workplace are restored.

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Проблемы вузовской подготовки и развитие инженеров на рабочем месте

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Особенности отечественного инженерного образования кратко рассмотрены с точки зрения исторической ретроспективы. На этой основе современная подготовка специалистов в технических вузах оценивается критически в связи с отсутствием ясных перспектив на ближайшее будущее. Лучшие перспективы имеет подготовка инженеров в системах непрерывного профессионального образования на промышленных предприятиях. Помимо целевого обучения в вузах большое внимание в этих системах уделено развитию инженеров на рабочем месте. Это требует определенных предпосылок, включающих создание благоприятной среды для обучения и наличие там обучающего потенциала достаточной величины.

Ключевые слова: подготовка инженеров, образовательная политика, непрерывное профессиональное образование, ситуативное обучение, обучающий потенциал.