The role of cluster initiatives in educational systems in the improvement of engineering and technology education

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ABSTRACT: The role of all school system levels in the education of qualified workers, particularly vocational school graduates, the users and exploiters and engineers and technologists (technical university graduates), the creators and initiators of technology and innovation are presented and discussed in this paper. The research questions discussed are: what is the Polish experience and perspective in engineering and technology education and how can the education system be improved to become an object of an innovative economy. The paper highlights the attitudes of particular levels of the educational system, indicates the advantages and threats, and describes the essence of creation cluster initiatives in the area of education, as a proposal to adapt education match the needs of the innovative economy. The proposal is based on integrated research and monitoring of the cluster initiative's participants.

INTRODUCTION

Polish engineers support the process of innovation and that is why the Polish economy can become more innovative, especially through technology transfer. Innovation and competitiveness are determinants of functioning and developing companies and the economy. Particular workers with their individual qualifications, knowledge, attitudes, skills and ability to work in teams can stimulate or disturb innovation and competitiveness. They are:

1. Qualified workers (vocational school graduates) - users and exploiters of technology and innovations; and
2. Engineers and technologists (technical university graduates) - creators and initiators of technology and innovations.

An innovative economy needs both groups of workers and both groups have a great influence on the creation of an innovative climate. First, new technologies, products and ideas are mostly designed by well educated, qualified and skilled university graduates. Second, no sector of industry will manage without qualified workers (unqualified workers make mistakes and generate losses). The workers most required in industry are (accordingly to the authors' research): welders, metalworkers, electricians and electronic specialists [2]. Maintenance services are (or should be) based on workers' qualifications and skills in a particular industrial company and in authorised services. Engineers cannot be substituted with economists, sociologists, financiers, politicians and entrepreneurs [1]. One characteristic of engineers' work is that it involves innovation in the current work and is continuously focused on new ideas and solutions. Moreover, their work is connected with high risk, responsibility and the need to make quick decisions.

The research questions in this paper are:

1. What is the Polish experience and perspective in engineering and technology education?
2. How can the education system be improved to match the needs of an innovative economy?

From this background, it is necessary to discuss the role of the school system and if there is any, engineering and technology education.

EDUCATION FOR AN INNOVATIVE ECONOMY

Education for an innovative economy is carried out in every type of school. Formally, universities of technology are responsible for the education of engineers, but the whole process begins at primary school, or even in kindergarten and at home. Students' natural interest in the world and environment can, and should, be used in the construction of

educational systems. Independently of educational programmes, schools and their directors have a considerable autonomy and have the opportunity to create a climate of creativity and innovation at schools.

To discuss the research questions there is a need to begin with a short description of the Polish educational system (the school level):

- *Primary school* (six years), six-year-old children begin school education.
- *Lower secondary schools - gimnazjum* (three years).
- *Basic vocational school* where students have to attend for a minimum period of two or three years. On completion, they have to pass a practical examination in acquired skills to obtain a diploma.
- *General secondary schools* (three years). On completion, school students can sit for the matriculation examination.
- *General secondary schools with a profile* (three years). On completion, school students can sit for the matriculation examination. This type of school was very unpopular among lower secondary school graduates and these schools are being closed systematically.
- *Technical and vocational secondary schools* (four year) offer a broader scope of general education, as well as a technical diploma, students can sit for the matriculation examination.

According to the research carried out by the authors, the most important problems in management in the area of vocational education are [2]:

1. Increasing numbers of lower secondary schools graduates choosing general secondary schools and willing to continue education at universities.
2. Decreasing interest in vocational education.
3. Lack of information of labour market requirements and insufficient cooperation between the labour market and the educational system.
4. Graduates' qualifications, skills and attitudes do not meet the labour market needs.

The popularity of general education caused the increase in the number of general schools. Local governments, which are responsible for educational management concentrated on organisational, merit and financial supervisory, were likely to open general school and closing vocational ones, for two main reasons.

First, they fulfil students' educational needs, and second, they save money, because vocational education is more expensive. Presently, general secondary schools are divided into two groups:

- Top level general secondary schools (as they have been for decades) with a high level of education, creative teachers, graduates studying at top universities according to their choices.
- Other general secondary schools, created in place of closed vocational schools, with poor examination results. Directors and teachers (a group of 278 interviewed in February - September 2011) stated that many of those students should not attend general secondary school, and that vocational schools would be more appropriate for them than theoretical study at a general school.

Most secondary school graduates who passed the matriculation examination go on to study at university. Some local governments realised the problem and supported vocational education and cooperated with local labour market, with good results. Others seem not to understand labour market requirements and do not develop vocational schools. In that case, scholarly indicators increase, but not the quality of education.

School-level education prepares students to became exploiters and creators of technology and innovation in the future, whereas university-level education creates such engineers.

Who are the good engineers and how should they be educated? That is the basic question for universities of technology. Profiles of graduates contain descriptions of theoretical knowledge, practical skills and specific attitudes, but it is more difficult to achieve this profile than to write about it in university marketing materials.

Who is (should be) an engineer?

> *An engineer is a professional practitioner of engineering, concerned with applying scientific knowledge, mathematics and ingenuity to develop solutions for technical and practical problems. Engineers design materials, structures, machines and systems while considering the limitations imposed by practicality, safety and cost. Engineers apply techniques of engineering analysis in testing, production, or maintenance. Analytical engineers may supervise production in factories and elsewhere, determine the causes of a process failure, and test output to maintain quality. They also estimate the time and cost required to complete projects. Supervisory engineers are responsible for major components or entire projects. Engineering*

analysis involves the application of scientific analytic principles and processes to reveal the properties and state of the system, device or mechanism under study. Engineering analysis proceeds by separating the engineering design into the mechanisms of operation or failure, analyzing or estimating each component of the operation or failure mechanism in isolation, and re-combining the components [3].

An encyclopaedia definition indicates particular engineering skills and the abilities to work in dynamic, uncertain, risky but creative fields that are full of challenges and provide an ambitious work environment [3].

How are engineers educated?

Polish universities of technology educate engineers in a two-level system. The first level covers three and a half years of study and ends with the preparation of an engineering project and sitting for a complex examination. Students that complete all requirements receive the title *engineer*. The second level covers one and a half years and is completed by preparing a Master's project and Master's examination.

Education is a process. The level of graduates of university of technology depends on both:

- The education process at university; and
- The knowledge, skills and abilities of first year students (an important part of the entrance data of the educational process).

The worse is the knowledge and skills of first year students at university, the more difficult it is to educate a good engineer.

The following advantages of the Polish university system have influenced engineering education:

- Autonomy in the creation of programmes (syllabuses).
- To complete subsequent semesters, students must prepare projects in various subjects. They involve careful study, are concentrated on improvement of existing results and seeking new ones - creative and innovative.
- Cooperation with business (industry), ability of students to undertake vocational training in companies from a wide range of sectors of the economy.
- The strong position of career offices at Polish universities. They play the role of recruitment offices, cooperate with employers, organise training and offer vocational advice.
- Creation of skills such as independence, creativity, decision making and dealing with risk during the study process.
- The increasing role of technology parks (transfer of technology).
- Promotion of enterprise among students (spin-off and spin-out businesses).

The most important threats to an innovative economy are demographic gaps and the lack of an entrance examination (recruitment is based on matriculation examination results). A demographic gap, presently existing in primary schools, will eventually become visible at the university level. Despite the educational boom (*everybody is going to study*), the structure of universities is very wide and universities try to recruit as many students as possible.

The number of places at university depends on the structure of employment and is mostly constant but the number of good candidates (with good results at the matriculation examination) is decreasing accordingly with demographic trends. The entrance knowledge and skills of future engineers (first year students) has been declining for 10 years, since the first lower secondary school graduates (completed secondary school education) entered universities.

The current situation in Polish education has been formed by the *Educational System Reform*. The new school system was introduced in 1999. The essence of the *Educational System Reform* was to introduce the new school system (new types of schools: lower secondary school and general school with profile, the length of education in particular types of schools has changed) and to give tools to local governments to achieve the following:

- to increase the number of graduates at secondary and tertiary levels;
- to equalise educational opportunities; and
- to improve the quality of education.

In engineering education, the reform of programmes has introduced and initiated threats. Attitudes to the educational system (at the levels of lower secondary and secondary school) have a negative influence on the future education of engineers and, generally, on the economy, because of:

- insufficient amount of teaching in mathematics and the natural sciences,
- education with insufficient pressure for creativity, looking for solutions and solving problems,

- students' and parents' belief that almost everyone can obtain a university degree and that not much is required to achieve it,
- completion of the matriculation examination with 30% of correct answers; it is easy to pass the examination at the basic level.

The decreasing skills of secondary school graduates has been caused by more than the educational system reform, particularly by a small amount of mathematics and environmental sciences. A demographic gap has also appeared at the school level. School directors avoid teachers' redundancy and local governments are afraid to close schools.

The system of financing the educational system is based on payment per student. The more students at school, the less the risk of teachers' redundancy. Unreasonably, maintaining of poor schools (especially general secondary schools), supported by educational needs (and the belief that *everybody can learn in general secondary school*) causes a lot of damage to education.

EUROPEAN INNOVATION SCOREBOARDS VS EDUCATION QUALITY

The problem of measurement of innovation has been widely analysed and the methodology (especially particular indicators) are constantly being evaluated in Europe [4-8]. The most advanced is a proposal of the European Commission (used since 2000): The Innovation Indicator Scoreboard used and developed till 2009, and the Innovation Union Scoreboard in 2010 (EUS). In the EUS report 2010, indicators are grouped into three areas and eight dimensions (Table 1).

The overall innovation performance of each country is summarised in a composite indicator (the Summary Innovation Index). The methodology is divided into following steps [8]:

- Identifying and replacing outliers.
- Setting reference years.
- Imputing for missing values.
- Determining maximum and minimum scores.
- Transforming data if data are highly skewed.
- Calculating re-scaled scores.
- Calculating composite innovation indexes.

Table 1: Innovation Union Scoreboard 2010 [8].

Areas of innovations	Dimensions	Indicators
ENABLERS	Human resources	New doctoral graduates
		Population completed tertiary education
		Youth with upper secondary level education
	Open, excellent and attractive research systems	International scientific co-publications
		Scientific publications among top 10% most cited
		Non-EU doctoral students
	Finance and support	Public R&D expenditure
		Venture capital
FIRMS' ACTIVITIES	Firms' investments	Business R&D expenditure
		Non-R&D innovation expenditure
	Linkages & entrepreneurship	SMEs innovating in-house 30.3
		Innovative SMEs collaborating with others
		Public-private co-publications
	Intellectual Assets	PCT patent applications
		PCT patent applications in societal challenges
		Community
		Community designs

OUTPUTS	Innovators	SMEs introducing product or process innovations
		SMEs introducing marketing/organisational innovations
	Economic effects	Employment in knowledge-intensive activities
		Medium and high-tech product exports
		Knowledge-intensive services exports
		Sales of new to market and new to firm innovations
		Licence and patent revenues from abroad

The complete and advanced methodology allows innovation to be measured and compared with particular countries, and indicates those elements which are important in the creation of an innovative climate. On the basis of research and the authors' experience, there is a need to discuss the first three indicators of human resources in the area of enablers:

- New doctoral graduates.
- Population completed tertiary education.
- Youth with upper secondary level education.

Polish indicators have improved and seem to be getting better. An indicator of the number of graduates from particular types of school does not give full information. It is also important to measure education quality, but it is impossible to measure with the quantitative indicators mentioned above. External examination results are satisfactory in Poland (Table 2) and, so far, they are treated as the most important indicator of educational quality. The Ministry of Education has introduced a measurement system of a value-added educational indicator, based on the comparison of results at the beginning and end of education at a particular school. However, they are still internal measurements being used, which do not contain elements of labour market research.

Table 2: Results of matriculation examination in Poland and in the Silesia region between 2006 and 2010 [8][9].

	2006	2007	2008	2009	2010
Percentage of passed examinations in Silesia region	80.07%	89.99%	80%	81.18%	79.37%
Percentage of passed examinations in Poland	79%	90%	79%	81%	81.50%

On the other hand, employers are not satisfied with graduates with secondary school qualifications, skills and knowledge [1]. Universities' lecturers have also observed a decrease of students' knowledge.

CONCLUSIONS AND FURTHER RESEARCH - THE IDEA OF CREATION OF CLUSTERS INITIATIVES IN EDUCATION

The educational system is not an island and an innovative economy demands good cooperation between the labour market and the educational arena. This is understood at the university level, where cooperation between science and industry develops quickly and effectively. Local governments and school directors understand the necessity of cooperation with employers, recruitment offices and labour market institutions. Cooperation between vocational schools and employers is mostly connected with vocational training. The educational system is afraid of any external measurement based on labour market and graduates' opinions.

The authors have worked out the idea of supporting cluster initiatives in the educational system. Creating a cluster initiative in education should be spontaneous, not confined to artificial procedures and bureaucracy. The suggested concept has a double role. First, it will help to create the cluster initiative, and second, it will help with educational management and measurement of the quality of education, decision making, implementing processes and activities in cluster initiatives to develop it.

Potential participants of the cluster initiative (students, local governments, educational area, employers) will take part in integrated research, mainly:

- Collection of research-based information on labour market requirements.
- Collection of research-based information on students and the educational arena, and the requirements and abilities of local government and the labour market to fulfil those requirements.

Knowledge will be converted and transformed by the expert system. The basis of research is the monitoring and analysis of needs and requirements of all potential participants of cluster initiatives. Research will also provide information about abilities to fulfil this requirement. Pathways and ways of communication between these four groups will be created. A tool - the expert system - is a kind of *toy* for participants of the cluster initiative. Participants will use

the tool, create ideas to develop it, communicate with each other and make decisions in accordance with the knowledge generated by the expert system.

The innovative economy cannot afford to have a bad educational system and educate graduates who will not enter the labour market and become unemployed.

Perspectives of further research are connected with following theoretical and practical recommendations:

- There is a need to continue exploring the labour market and educational needs.
- There is a need to create a complex measurement system of educational quality, not only based on quantitative indicators.
- Educational research should be created with the help of scientific experts. This will help to create tools of educational management but not just documents with requirements (e.g. an expert system to support the creation of cluster initiatives in education in being prepared by the authors).
- The educational environment (local government authorities, directors, teachers, educational experts) should realise the importance of educational research and use the research conclusion in making their decisions.

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