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DEVELOPMENT OF TECHNICAL CREATIVITY IN HIGHER EDUCATION

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Abstract:

Technical higher education should provide to student/future engineer scientific and technical knowledge and skills for understanding and using various technical equipment, and also for designing and developing new or improved such equipment. In the paper, the necessity and some ways of developing the students' technical creativity are approached. One may appreciate that there could be a certain correlation between the gross domestic product per capita, number of patents recorded yearly per million inhabitants and the interest directed to the stimulation of creativity in the technical higher education. Activities aiming the stimulation of students' technical creativity, addressed in technical higher education system and the results obtained are presented. The experience accumulated in some universities of Romanian language is also succinctly described. The contents of university subjects aiming to provide to students knowledge and skills for developing their technical creativity are mentioned. Within applicative activities attached to these university subjects, various methods for stimulating the technical creativity were used. Thus, the students could learn ways in which they could find new or improved solutions for technical problems and also how they can protect the intellectual rights deriving from these solutions. The main conclusion refers to the importance of finding adequate ways and contents of activities aiming the stimulation of students' technical creativity.

Keywords: technical creativity, engineering education, gross domestic product per capita, number of patents, students' creativity stimulation, universities of Romanian language

1. INTRODUCTION

The higher education is considered as a tertiary education system, able to offer high professional knowledge and competences in certain fields of activity. Essentially, the higher education is achieved in universities and colleges for a duration of minimum three years and the obtained qualification is recognized by according a higher national diploma. There is also a second type of higher education, which refers to postgraduate studies. If we take into consideration the technical field, the graduates can obtain the title of engineers. Over the years, the engineers had a significant role in the evolution of the material component of the society and this could be frequently justified by their technical creativity; this means that the university should ensure a study environment able to stimulate and develop the technical creativity in a maximum extent.

When somebody analyses *the creativity*, he takes into consideration the capacity to generate at least something new or improved in comparison with the known situation. In 1937, Gordon Allport proposed a definition for creativity as being *an integrative way in which the human being was succeeding not only to understand, reproduce or solve many life problems, but also to generate new and original solutions* (Căpălneanu, 1978, p. 105). In such a context, *the technical creativity* could refer to the capacity of a person to invent objects, processes or methods having a technical character. Due to its high importance in the engineering activity, *the technical creativity* and the methods able to facilitate its development constituted an objective of researchers' preoccupation.

Thus, Badran highlighted the correlation existing between creativity and innovation, on the one part and the engineering education, on the other part (Badran, 2007). He proposed the generation of an engineering creative enterprise just by a better association between small and medium enterprises creativity and the business support creativity. With this aim in view, the engineering education systems could introduce engineering projects at all levels by earlier considering the industry requirements.

Da Silva Alves et al. noticed that the differences of objectives and strategies between universities and companies did not facilitate an efficient collaboration between these structures in the case of Brazil. (Da Silva Alves et al., 2015). They appreciated that new policies are necessary in order to improve the university-industry cooperation and to ensure, in this way, a more intense promotion of the innovation.

Gaspar and Mabic developed a research concerning the role of creativity in higher education by using distinct questionnaires for teachers and students in the University of Mostar from Bosnia and Herzegovina (Gaspar and Mabic, 2015). They noticed that if the problem of enhancing creativity in the academic community is formulated, there are differences in opinions between teachers and students. The students appreciated that the teachers do not encourage them enough to be creative and that the model of teaching is still *ex cathedra*. This means that additional efforts must be made in order to enhance creativity in teaching process, in research, management and other activities.

Nisula et al. took into consideration the possibility to foster team creativity and innovativeness in connection with the concept of playfulness and its implementation in practical situations (Nisula et al., 2015). They appreciated that in this way, the creativity and innovativeness could increase the efficiency on an individual level, on a group level and on an organizational level, respectively and that the playfulness could contribute to building open social connectivity and a space where the creativity emerges.

A proposal aiming not teaching creativity, but rather understanding and building up the creativity possessed by every student was formulated by Livingston (2010). He expressed the opinion that the education efforts could be focused not on what the teachers want the students know, but on what the teachers want the students could become.

The objective of this paper was to highlight the necessity to find and implement activities aiming to stimulate students' creativity and to present some results obtained in such a direction in several universities of Romanian language.

2. NECESSITY OF TECHNICAL CREATIVITY STIMULATION IN HIGHER EDUCATION

The significance of the higher education for the development of a state or a nation is clear; one can consider that without strong institutions of technical higher education, a medium or big state is not able to ensure the prosperity of its inhabitants.

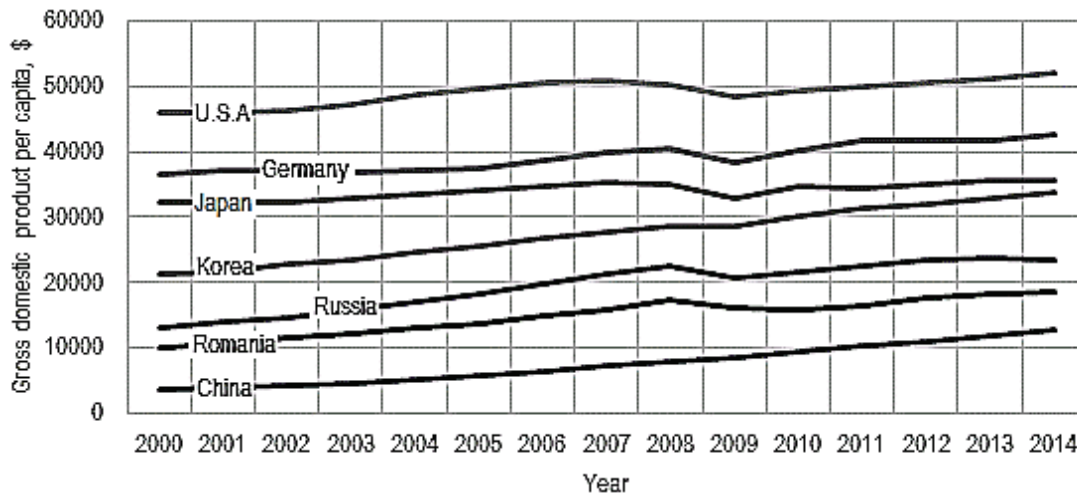
The technical higher education should firstly offer to the future graduate professional knowledge and abilities of solving technical problems; the future engineer must know how he can design, develop and apply a technical product or a process. With this aim in view, the university curricula include subjects of designing a product or a process, of using this product or process so that the production activity is efficient. The last decades proved that a training aiming only such objectives is not the best; the future engineer must know not only to design and develop known product and processes, but he must be educated/trained in order to generate improved or new products and processes. The question is if the higher education system is able to offer an adequate training in this direction or if new actions should be undertaken to maximally achieve such a requirement.

A possibility to evaluate the innovation capacity of a company, a nation or a state could be based on considering the number of annually recorded patent applications or patented inventions by the national offices with responsibilities in this direction.

Table 1: Evolution of population, of total gross domestic product (billions of dollars) and of number of patents for Republic of Korea, Japan, U.S.A., Germany, China, Russia and Romania over the period 2000-2014

Year	Republic of Korea			Japan			U.S.A.			Germany		
	Popu- lation, milli- ons	Total GDP	Num- ber of patents	Popu- lation, millions	Total GDP	Num- ber of patents	Popu- lation, millions	Total GDP	Number of patents	Popu- lation, milli- ons	Total GDP	Number of patents
2000	45	975	85783	126*	4083	490776	282*	12975	280390	83	3037	134691
2001	47	1019	88319	127*	4097	506637	285*	13102	290769	83	3089	137731
2002	48*	1095	94248	127*	4109	483806	287*	13336	291806	83*	3089	132836
2003	48*	1127	112754	127	4179	484943	290*	13710	301737	83*	3067	134631
2004	48*	1183	136438	127	4277	510023	293*	14229	330855	83*	3103	146047
2005	48	1229	162694	127*	4333	530005	295*	14705	383242	83	3125	153634
2006	48*	1293	173301	127	4406	517486	298*	15097	404260	83*	3241	160589
2007	49*	1363	176336	127	4503	508263	301*	15366	437353	83*	3347	163779
2008	49*	1402	173496	127*	4456	509990	304*	15321	428881	83*	3382	171835
2009	49*	1412	170233	127	4210	463601	307*	14896	397919	83*	3192	162332
2010	49	1504	178654	127*	4406	468417	309*	15273	433199	83	3322	173619
2011	50*	1559	187747	127	4386	475051	311*	15517	440632	82*	3442	175606
2012	50*	1595	203836	127	4463	490271	313*	15878	473489	82*	3454	183048
2013	50*	1641	223527	127	4535	473141	316*	16230	501162	82*	3458	184493
2014	50*	1695	230553	127	4530	465971	319	16618	509521	82	3514	179506
Year	China			Russia			Romania			The total gross domestic product (GDP) was expressed in billions of dollars. Sources for gross domestic product, number of patents and population: http://www.wipo.int/ipstat/en/statistics/country_profile/ , www.populstat.info/ , www.statista.com/statistics/263765/total-population-of-china/ , accessed in January 2016. For the years in which information was not found in accessible documents, the population was supposed as a consequence of a normal evolution (*).		
	Popu- lation, millions	Total GDP	Numbe r of patents	Popu- lation, millions	Total GDP	Numbe r of patents	Popu- lation, millions	Total GDP	Number of patents			
2000	1270	4644	26445	146	1931	24093	22	223	1028			
2001	1280	5029	31232	145	2029	25657	22	236	1147			
2002	1290	5486	41418	145	2125	24499	21	248	1494			
2003	1300	6036	58757	144	2280	25644	21	261	902			
2004	1310	6644	69017	144	2444	25040	21	285	987			
2005	1315	7399	97948	143	2600	25948	21	297	978			
2006	1320	8338	129290	143	2812	30575	21	323	903			
2007	1330	9521	161308	142	3052	30489	21	343	965			
2008	1335	10437	204268	142	3212	31095	21	370	1123			
2009	1345	11401	241434	142	2961	28859	21	345	1150			
2010	1340	12613	308326	142	3094	32837	21	341	1501			
2011	1347	13810	436170	142	3226	31464	21	349	1599			
2012	1354	14880	561408	143	3336	34379	20	351	1244			
2013	1360	16023	734096	143	3381	34067	19	363	1241			
2014	1367	17201	837817	146	3402	28512	19	369	1252			

Picture 1: Evolution of gross domestic product per capita over the period 2000-2014



In order to highlight the significance of the creativity stimulation for promoting innovation, a succinct analysis could be developed for several states. The analysis took into consideration the number of patents and the gross domestic product per capita for the following states: Republic of Korea, as one of the states characterized by an intense economic development in the last decades, Japan – as a state in which adequate ways were found in order to stimulate the activity of patenting and where remarkable results in patenting activities were obtained, United States of America - as the most important economic power in the world, Germany – as a state known for the significance given to development of technics and industry, China – as a state found in an intense industrial development and having the highest number of inhabitants, Russia – as a state where there was an intense promotion of methods able to stimulate the technical creativity and Romania, as a country of some of the paper authors.

In all the mentioned countries, a special attention is given to the development of technical higher education. For example, if the percentage of the tertiary education graduates in natural sciences and engineering is considered, one could notice that in 2012, this indicator had the value of 32 % in Republic of Korea (ranks first in the world), 31 % in Germany (ranks second), 23 % in Japan (ranks 12th), 16 % in U.S.A. (ranks 32) etc. (https://en.wikipedia.org/wiki/List_of_countries_by_graduates_in_natural_sciences_and_engineering). If the countries are analyzed from the point of view of the 25-to 34-year-olds having a tertiary education degree, one can remark that, in this list, Republic of Korea ranks first (63.82 %), Japan ranks second (58.70%), Russia ranks fourth (56.46%), Germany ranked 28th (27.67 %) etc. (https://en.wikipedia.org/wiki/List_of_countries_by_25-_to_34-year_olds_having_a_tertiary_education_degree).

The evolution of the gross domestic product and of the number of patents recorded by the national authorities as they are mentioned in the accessible documents are presented in tables 1 and 2; the period 2000-2014 was selected as a period characteristic for the new century and millennium and for which statistic information could exist.

In order to evaluate the significance of increasing the gross domestic product and also the interest directed to increase of number of patents, one considered that a better information could be given by the gross domestic product per capita and by the number N_p of patents recorded for a million of inhabitants. As a consequence, on the base of information presented in table 1, the above mentioned indicators (gross domestic product per capita and number N_p of patents for a million of inhabitants) were calculated and, as a result of these calculations, the diagrams from pictures 1 and 2 were elaborated. The graphical representation from picture 1 corresponds to the evolution of the gross domestic product per capita over the period 2000-2014. For almost all considered states, an approximately continuous low increase of the gross domestic product per capita could be observed. A certain decrease of the gross domestic product per capita appeared in the period of economic crisis started in 2008. The last statement is valid for all the considered states, with two exceptions,

corresponding to Republic of Korea and China, which were not significantly affected by the economic crisis and which had practically a continuous ascendant development.

The second indicator able to offer an image concerning the stimulation of the technical creativity was the number of patents N_p recorded for a million inhabitants. The analysis of the graphical representation from picture 2 shows also a certain increase of the indicator N_p for all the considered states. The increase is more intense also for the two states mentioned in the previous paragraph and namely for China and Republic of Korea. If some decades ago the Chinese industry was considered as essentially involved in reproduction of the industrial objects, in the last years a real remarkable attention was paid to the activities of patenting. If in 2000 only 26445 technical solutions were patented, in 2014 the number of patents was of 837817 and this represents a remarkable increase of more than 30 times. One could also notice that if the number of patents for one million inhabitants is taken into consideration, from 2011 the Republic of Korea exceeds the performance of Japan, previously known as a good promoter of the patenting activities.

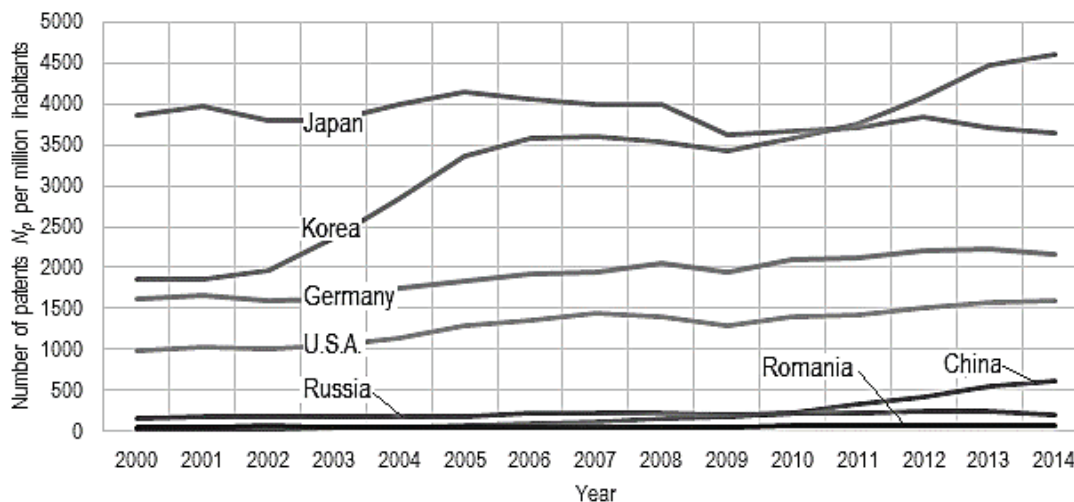
The analysis of the information included in pictures 1 and 2 shows that there is a certain correspondence between the increase of the intensity of patenting activities and the increase of gross domestic product per capita, respectively. Among the considered countries, Republic of Korea and China known the most intense increase from the point of view both of gross domestic product per capita and of the number of patents N_p per million inhabitants. These countries are known also for the appreciable attention directed to the higher technical education and the above mentioned results (increase of gross domestic product per capita and of number of patents per million inhabitants) could be connected with the significance directed by the states to the technical higher education and to the stimulation of technical creativity.

3. WAYS OF STIMULATING THE STUDENTS TECHNICAL CREATIVITY

There are many ways in which the technical creativity could be stimulated within the technical higher education, in a certain correspondence with the variety of formal or informal university activities.

Thus, the analysis could be started by discussing the possibilities offered by *the university lectures* to contribute to the technical creativity stimulation. Within their lectures, the professors could highlight the main technical problems for which adequate solutions were not found. The professor could also show to the students that the information presented within lectures corresponds to a certain stage of science and technics and that there is a possibility that just during their activity in the field of technics, this information could be affected by significant changes. In these changes, the students themselves could be involved and they also could contribute to them. One of the current requirements valid in the case of lectures is the promotion of an active attitude, this meaning that the students could formulate questions just during the lectures and this could be an interesting way of encouraging and promoting the technical creativity.

Picture 2: Evolution of patents number per million inhabitants over the period 2000-2014



During *seminars activity*, the information concerning unsolved technical problems could be also highlighted and one must notice that more time (in comparison with the time dedicated to lectures) could be given to discussing technical problems and ways of their solving.

The applicative activities such as *laboratory work* could also contribute to stimulation of technical creativity. It is well known sometimes the critical spirit of the student or generally speaking of the young age; the students are tented to observe the possible deficiencies or possibilities to improve the laboratory equipment or processes. One can appreciate that the didactic staff could contribute and orient with tact such normal critical trends for solving proper technical problems in an original way.

The design and development of *semester or yearly or diploma projects* could be also used in order to force the development and the use of the student technical creativity. Generally, the students could know that original solutions of problems formulated as project topics could be better appreciated by the diploma boards and even by technical practice.

A direct involvement of student in solving practical problems could correspond to periods of *technological practices/ interships*, when the future engineers could be oriented not only to the accumulation of practical knowledge or competences, but they could be encouraged to find new or improved solutions for technical problems.

In certain universities, there are activities in which students must solve scientific problems or technical problems involving a high scientific component, but considered as accessible for their training level. Usually, the students are guided in improving their scientific abilities by the teachers or just by a student having a higher scientific level (master student or PhD student). This could be also a circumstance when the student could be oriented to find original or improved solutions for the problems to whom he must cope.

It is clear that during the activities of elaboration of *master dissertation or PhD thesis* in technical fields there are significant possibilities to develop and efficiently use the technical creativity.

If the above mentioned activities are placed where the technical creativity could be directly encouraged and applied, one could also mention that over the years the researchers searched and found an impressive number of methods able to be applied in order to facilitate finding of new or improved technical solutions. In the web page https://www.mycoted.com/Category:Creativity_Techniques, near 200 methods of stimulating technical creativity or the creativity in general are mentioned. Such techniques could be certainly applied in various university activities in order to stimulate and use the students' technical creativity.

The researchers considered that the high level of patenting activities developed in Japan is the result of knowing and applying adequate methods and techniques for creativity stimulation. For this reason, initially there was considered as a certain surprise the statement formulated by the researcher Tan al Girl (1997). This researcher considered that, in the case of Japan, more valid is the opinion expressed by American psychologist of Hungarian origin Mihaly Csikszentmihalyi, who was saying that the insurance of a background able to stimulate the creative thinking is more important than the promotion of activities oriented to knowing and learning creative techniques.

4. EXPERIENCE ACCUMULATED IN SEVERAL UNIVERSITIES OF ROMANIAN LANGUAGE ABOUT THE STIMULATION OF STUDENTS CREATIVITY

In the "Gheorghe Asachi" Technical University of Iași – Romania, several decades ago, professor Vitalie Belous was the first university professor who formulated the problem of finding methods able to stimulate technical creativity, both in case of students and of the engineers working in enterprises. Initially, in the '60 years of the previous century, he founded a real extracurricular school of inventics and conferences and symposiums were organized, in order to discuss problems in connection with the activity of generating and patenting technical solutions.

Within these schools of inventics, the professor Belous organized courses dedicated to the engineers from enterprises. Afterwards, as a consequence of his initiative, optional courses aiming to stimulate and develop the students' creativity were included in the curricula of study programs existing in the former Faculty of Mechanics. Professor Vitalie Belous organized also conferences and symposiums

where problems specific to the so called inventics were analyzed and various methods able to facilitate the promotion of the technical creativity were analyzed, in order to be applied by students and engineers.

Nowadays, a university subject called “Fundamentals of technical creativity” is included in the curricula of several study programs. Essentially, the lectures corresponding to this university subject present to the students distinct methods applicable in order to stimulate the technical creativity.

An important chapter of the lectures is dedicated to factors able to stimulate or to act as obstacles in the activities aiming to promote the use of the technical creativity. We consider that in this way, the student/ the future engineer could have more information concerning the difficulties possible to be met in his activities of introducing new or improved technical solutions.

As a direct result of the activities initially promoted by professor Vitalie Belous and also developed by his collaborators, one can mention that there were periods when 5-10 % from the Romanian patents were proposed by students and professors from the “Gheorghe Asachi” Technical University of Iași. Yearly, the students and professors from the university of Iași were sending to the Romanian State Office of Patents and Trades about 150-200 patents applications. In picture 3, one can see several patents whose first authors or single authors were, in that time, students of the “Gheorghe Asachi” Technical University of Iași. Also as a consequence of the activities promoted initially by professor Vitalie Belous, in 1992 in Iași was founded the National Institute of Inventics, designed as a significant research institute and promoter of the inventics in Romania.

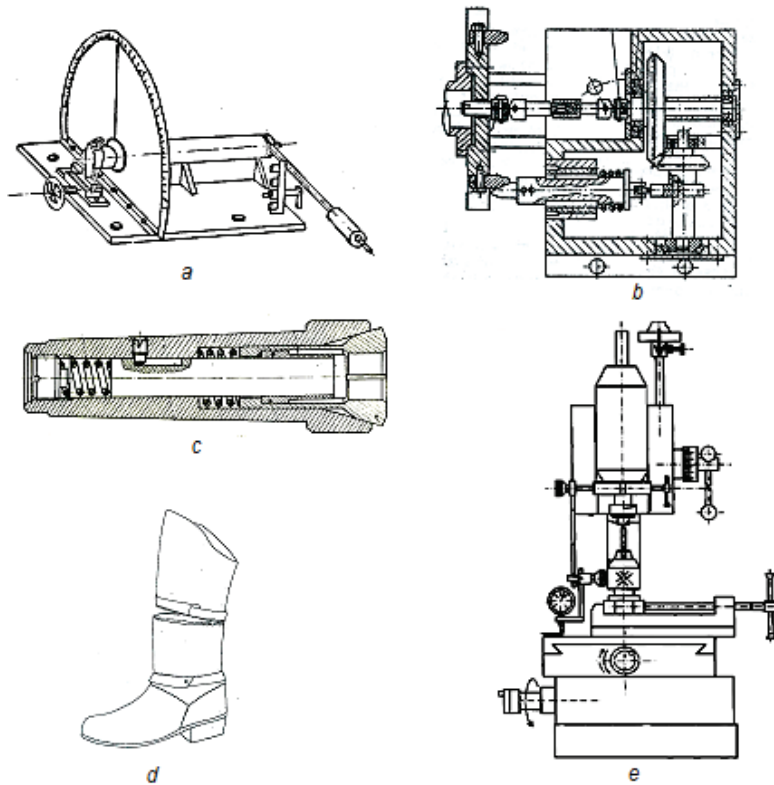
Yearly this institute organizes a saloon of inventions and a conference in which problems specific to the promotion of the technical creativity are debated.

Professor Belous initiated also the publishing of handbooks valid for the field of inventics (Belous, 1986; Belous, 1990; Belous and Plahteanu, 2014 etc.); such handbooks were also elaborated by other professors involved in activities of students' creativity stimulation (Nagîț, 2001; Slătineanu and Dușa, 2002; Slătineanu, 2015 etc.). In order to highlight the significance of training the future engineer for generation of new or improved technical solutions, professor Belous was saying that the engineer must have four important functions / responsibilities: *the engineer must know technics, must apply technics, must lead groups of specialists in technics and must generate new technics* (must generate new or improved technical equipment and processes) (Seghedin, 2010).

In order to involve the master students in the field of generation and protection of the original technical solutions, for some master studies programs, a subject concerning the industrial property was included in the curricula.

At “Ștefan cel Mare” University of Suceava – Romania, the main promoter of activities aiming the stimulation of the students technical creativity was professor Dorel Cernomazu (1947-2015), one of the most important Romanian inventors; over the years, professor D. Cernomazu and his collaborators patented more than 300 technical solutions. Within the Faculty of Electrotechnics, professor Cernomazu succeeded to really promote the technical creativity, so that in the last years, “Ștefan cel Mare” University of Suceava was situating on the first place in Romania, if the number of patents applications is considered. For example, in 2011, the students and the professors from this university recorded 88 patent applications, while the number of patents applications was of 32 for the “Gheorghe Asachi” Technical University of Iași, and 34 for the Politehnica University of Bucharest etc.

Picture 3: Patents for which the first author or the single author was a student: a – device for measuring the cutting energy (Ciulică M. et al., patent Romania no. 65424/1975); b – device for sharpening the tools for head used in order to machine conical gears in arc of circle (Cioban G. et al., patent Romania no. 71440/1978); c – chuck with elastic sleeve (Colceriu E., patent Romania, no. 86708/1983; d – transformable shoes (Ilade C., patent Romania no. 110293/1994); e – device for study the machinability by cutting under constant force feed (Gherman, L. et al., patent Romania no. 128618/2011)



An intense promotion of the activities aiming to stimulate the students' technical creativity was developed in the Technical University of Moldova of Chişinău (Republic of Moldova). Professors Ion Bostan and Valeriu Dulgheru encouraged the students and professors in patenting their original technical solutions. They elaborated also handbooks to be used in various activities able to stimulate the technical creativity and to ensure the legal protection of objects of industrial property. A university subject called "Technical creativity" was included in the curricula for all the study programs valid for the students of the Faculty of Mechanical, Industrial and Transport Engineering. During the activities corresponding to this university subject, the students learn how they could use various methods able to stimulate the technical creativity (brainstorming, sinectics, value analysis, TRIZ etc.).

5. CONCLUSIONS

The specialty literature highlights the significance given by researchers in finding and applying adequate techniques and methods able to stimulate the technical creativity in the university environment. The number of papers and books in which the problems of efficient use of technical creativity increased constantly over the last years.

One can notice that there is a certain correspondence between the patenting activities and the increase of the gross domestic product per capita. The analysis of statistical information proved that in the cases of Republic of Korea and China (two states with distinct levels of development, but found in a real and continuous economic and technical progress in the last years), in the period 2000-2014, the effect of the economic crisis were less evident; more than this, over the above mentioned period, the gross domestic product per capita and the number of patents reported to a million inhabitants were recorded a real continuous increase.

One can also observe that in the addressed cases, the increase of the gross domestic product and of the number of patents could be correlated with the significance given to the training students in order to efficiently use their technical abilities and creativity.

The preoccupations of the universities to find and apply adequate methods able to educate the future technical specialists for an efficient use of their creativity led to the introduction of university subjects

dedicated to a better delivering of the technical creativity and methods and techniques applicable in this view were studied and used.

The experience accumulated in some universities of Romanian language showed that the researches and real applications of methods able to stimulate the technical creativity are especially the results of the activities developed by some professors with remarkable activities in this field, but gradually the university leaders were involved in the activities aiming the stimulation and efficient use of technical creativity by the students and professors.

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