Towards New Electronics Curriculum In Serbia

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I. INTRODUCTION

The quantity of global knowledge in the world grows very fast. One may consider it is proportional to the volume of a sphere which radius rises linearly with time. Our profession considerably contributes to this trend. We may claim that there is no other vocation with similar impact on human society.

However, unlikely to the positive influence on the surrounding world, electronics engineers (EE) are not recognized and respected as they should be. This started from the very beginning of electronics. W. Brattain, J. Bardeen and W. Shockley have waited eight years to be awarded for inventing transistor by the Physics Nobel Prize in 1956. Moreover, Jack S. Kilby waited almost 50 years to receive in 2000 the Nobel Prize for his part in the invention of the integrated circuit.

Despite to the status, this field of science is spreading much faster then the education system is able to follow. This is particular problem for poor countries and countries in transition. Good EE education requires money for sophisticated equipment and experienced trainers.

The goal of this paper is to initiate discussion on subject how and what to teach today in order not to jeopardize the future. Unlikely to classic scientific papers, my intention is not to give final solution for the topic. I doubt that anyone is able to do this in the moment. Instead, I'll try to give small contribution by considering three topics. Firstly the next two sections will discuss current position of EE, particularly in Serbia. Secondly, we will try to find out how to improve EE status. The one of solutions requires innovation of electronics curriculum. therefore, the paper will conclude with general observation of future EE education.

II. POSITION OF EE IN THE WORLD

It seams that the current position of EE in USA can be used as a benchmark for the rest of the world. However, one glance on the third column of Table 1 indicates that Physicians & surgeons starts with almost twice higher earnings then electronics/computer engineers. Comparing with lawyers the rate is 1:1,5.

According to [Gib02] in USA during 2002 Electrical and Computer engineers dominated over other engineering disciplines as Fig. 1 shows.

A good news is that median incomes for EE rise faster then the inflation rate [Bel97]. Unfortunately the engineering unemployment rose in 2002 from 4.1% to 4.8% despite the overall unemployment felled [Lyn02]. Moreover, the unemployment in computer science rose from 4,8% to 5,3%.

Table 1

Occupation	2002-2012 employment growth [%]	Median annual earnings [$]
Physicians & surgeons	19.5	>138,400
Lawyers	17.0	90,290
Computer soft. eng., systems software	45.5	74,040
Computer hardware eng.	6.1	72,150
Computer soft eng., applications	45.5	70,900
Electronics engineers, except computer	9.4	69,930
Economists	13.4	68,550
Electrical engineers	2.5	68,180
Computer programmers	14.6	60,290

(data derived from U.S. Department of Labor Bureau of Labor Statistics, www.bls.gov)

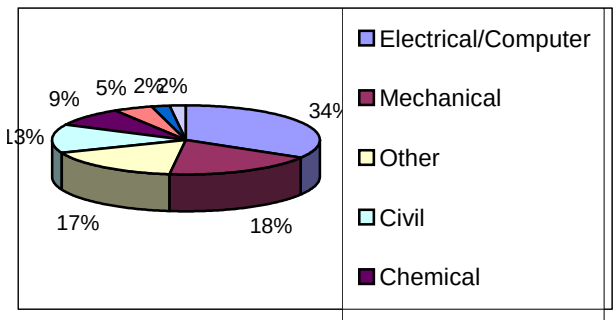

Fig. 1 Engineering disciplines in USA in 2002

The situation is not better in Taiwan where “a new EE, just out of university with no experience, can expect to make from $900 to $1,200 per month" [Car99].

EEs are in similar position in Germany [Mat02].

As result, the interest for studding electronics and computer engineering in Germany decreased from 21000 to 11000 between 1980 and 1990. After stagnation it is rising again from 1997.

III. CURRENT POSITION OF EE IN SERBIA

The gloom image of EE in the world becomes almost black when we focus on Serbia. Actually, break-down of overall industry in Serbia during the eighties was

accomplished by the sanctions at the beginning of the last decade. It was the time when I asked the authorities at the faculty to buy 5 transistors BC108 for laboratory exercises but they were able to buy just 2! Thinking about new instruments was equal to science-fiction. Firstly, there was no money; then there was no instrument produced in the country and, at least, there was no legal possibility to import an instrument from abroad. The same situation was with components. Of course, we have smart people in our country with very good smuggling skills. They help us to survive, but we paid and still are paying the price.

Although the all industry was stopped, we still had very good exporting product – engineers. Basically electronics engineers. Many of my colleges and I used to say, with proud, that our "products" are best-sellers on the world market.

Now I often ask myself if it was really our success or our defeat?

In comparison with all other productive occupations the position of EE was good for the people who wanted to start new life far away from the disturbed Balkan region. The immigration policy in many countries from Canada to New Zeeland encouraged a lot of young people (under 40 years old) to settle in alternative homeland. They had opportunity to work in the field of electronics, to attend many advanced courses, to cope with real problems related to manufacture and they growth up in very good engineers. Most of those people are ready to help colleges in Serbia. Fortunately, some of them have good positions now. We, as their professors, are proud to say they were our students.

However, it is very depressing to see another army of young EEs that were not able to find job on the native soil and had not enough courage or reasons to left parents. A lot of them started jobs that have no connection with Schrödinger's equation. They began carriers as cigarette, money or, at the best, computer dealers. Unfortunately, their agony is not finished yet. I feel very sad every time seeing my colleague that works as a salesman assistant in a supermarket. Moreover, I feel some kind of shame when I see any of my ex-student working something else trying to earn for living. Then we should all ask ourselves whose wrong investments were they?

Fortunately, despite to all obstacles, there are EEs who started their own job here in Serbia in Nish. (In fact, the number of self-employment engineers is modest even in developed countries with long free-market tradition: in USA it is between 3-4,7%). It is real pleasure looking how their companies grow up. That put us in position to be satisfied with the fruits of our work. Maybe they are cleaver or luck enough to succeed independently of education, but they are giving us hope that electronics engineering has future in this region. For them, and all other future students we should ask ourselves "What to do in order to improve status of EE in Serbia?"

IV. HOW TO IMPROVE STATUS OF EE IN SERBIA?

There are three subjects that are responsible and therefore in charge to find the solution:

- state
- industry
- universities

The **state** affects our lives through several appearances: as municipal, regional, republic and federal government. They have the key role in defining strategies. The federal and republic governments have to define national strategy and to mach it with

strategies of neighboring countries and EU. Good examples for the impact of state on position of EE comes from Alaska [Kei02] and New Hampshire [Eco01] where average wages are much higher then in the rest of US and predicted growth of employment in 1998-2008 is greater then 30%.

The idea of founding innovation centers in Serbia seams to be very promising. We may expect that innovation center Nish helps in reestablishing our town as industrial center of the south-east Serbia. This way of thinking (and doing) is suitable illustration how republic and municipal governments can influence on engineering profession.

The state(s) in all forms have to prepare framework that will regenerate industry. In better production oriented environment there will be more jobs for engineers.

Industry has changed its profile during the transition. Instead of strong "Elektronska industrija" with more than 30000 employees, now we have small and medium enterprises. Big factories are patient to accept engineers with wide theoretical background and rich enough to invest in additional education. They easily can to employ teams of engineers that are able to solve complex problems. The spectrum of their products is as broad as the knowledge they want from their engineers.

Oppositely, owners of small factories want to employ specialists capable to solve problems in the narrow area of their production interest. When vendor decide to change sort of product he changes the expert.

Universities are directly responsible for quality and quantity of knowledge offered to their students. Figure 2 shows difference between this two values.

The quantity of knowledge of an EE determines his price on the labor market. Simultaneously, the worth of a school is measured in number of valuable engineers it produced.

In order to create high rated engineers, universities in Serbia have to adjust their curricula. The guidelines for an innovated curriculum lies in structure of knowledge an engineer needs to stay competitive on the labor market.

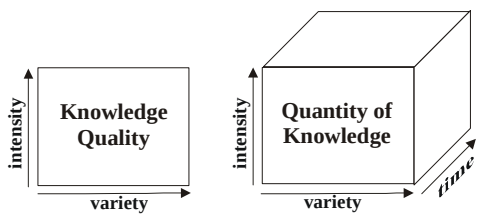

Fig. 2. Quality and quantity of knowledge

The improvement of the EE status lies in clearly differed professionals from dilettantes . Like MVP in basketball, the most valuable engineer (MVE) should be paid more than others. That will arise competition for knowledge and real values in our society.

V. THE POWER OF KNOWLEDGE

Electronics engineering requires managing with very wide knowledge. Figure 3 shows set of disciplines engaged in electronics. Its trapezoidal shape tends to illustrate how small contribution in materials stirs up development of new devices, circuits and

systems. The area of each trapezoid corresponds to the number of engineers involved in the field.

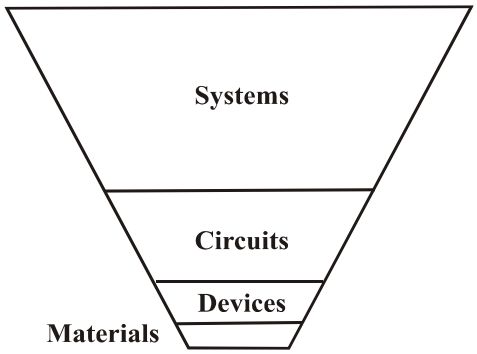

Fig. 3. Disciplines engaged in electronics engineering

This figure shows increased need for system engineers. Today their number exceeds all other engineers and their voice is louder. All of them claim that present electronics can sustain entirely on systems and consequently, there is no need to study circuits or devices. Unfortunately, they forgot that new systems relay on new circuits, devices and materials. When we exhaust possibilities of current FPGAs who is going to design the next one? Who will be able to understand how it works and why it does not work in certain circumstances?

Definitely, an ideal engineer should know all disciplines, but is it possible? When we talk about 'all' disciplines we think about variety of the knowledge, as Fig. 2 shows. Simultaneously, we have to consider intensity, or magnitude of knowledge. This opens the question of optimal intensity/variety ratio that an engineer needs to achieve desired quality of knowledge. What is better (or less worse): to know everything about nothing or to know nothing about everything?

For the future labor market in Serbia we can count on small enterprises. As we have pointed out previously, they will prefer engineers specialized in particular fields. However, every EE should ask himself is it worth to tie his destiny to current trends in electronics. It may be very dangerous because trends are changing quickly in this discipline. The treat of loosing job increase with the narrowness of the field. This is one of reasons why the tenth trend for the future in [Sch99] is "retreat from subspecialization".

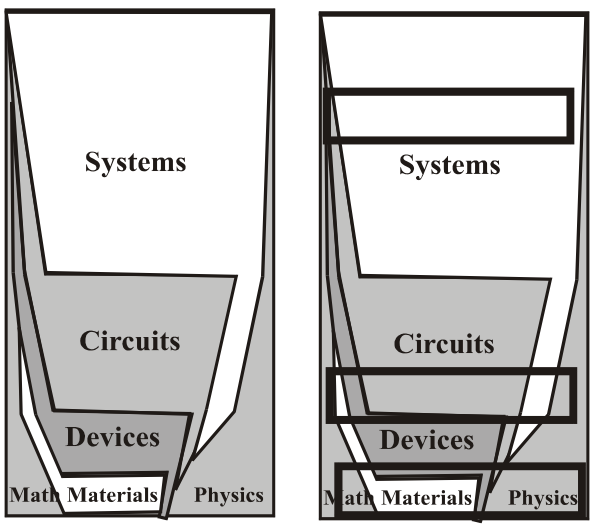

Fig. 4. a) The area of needed knowledge for EE
b) Example of three possible curricula for EEs with the equal qualifications in different fields.

The area of needed knowledge (quality) is presented in Fig. 4 a). Obviously, it is hard to

image an electronics curriculum capable to encompass the overall area.

Understanding basic principle of materials and devices requires more fundamental knowledge of physics and mathematics. Climbing up toward systems, one needs less subjects related to elemental scientific branches.

Instead a rigid school organization, the credit system proposed by Bologna Declaration (signed by Serbian authorities) offers flexibility in choosing area of prospective knowledge. Therefore three different students may choose three different area with the same knowledge quality, as Figure 4 b) shows.

Another issue is time of studding. It puts into scope quantity of knowledge. What is the proper measure for average students?

From the state's point of view the study should last as short as possible – it is cheaper. Students have the same attitude. Their interest is to start work and to get back money they spent during study. Therefore they prefer to find job and postpone investments into the own future by additional learning. This trend was noted in US in 2001 [Gib02].

In contrary, the appropriate knowledge quantum needed for MVE requires longer studies.

The student's ability to percept some dose of knowledge is subjective. Therefore it is good to personalized it. Future students must have chance to choose not only the quality but the quantity of knowledge, as well. This will make differences between engineers.

Another aspect of good curriculum is the amount of practical skills it may develop. The main weakness in our current EE education is the lack of hands-on training. When/if the innovation centers open, they will be good teaching polygon for students.

Although the field of electronics is very wide and getting bigger every day, modern EE have to posses skills from some other professions. Along with the impact our gorgeous profession have on all others, EE needs knowledge related on different fields from biology, and medicine to mechanics and aerospace. Besides, the future engineer needs non-technical skills, as well [McG99]:

- The ability to lead, influence, and persuade.
- The ability to deal effectively with ambiguity and take risks.
- Decision making and sound judgment.

All this implies that EE needs lifetime education.

VI. CONCLUSION

Given survey of skills and knowledge an EE needs, did not cope with particular branches within electronics engineering like control systems, robotics, telecommunications, power electronics... Besides it was no place in the paper to distinct electronics in different frequency domains or different technologies. Even without them the presented field of required knowledge is wide enough. Therefore it is difficult to imagine one school that will be able to offer to future students an unique curriculum that will result in universal electronics engineer.

At least it is impossible until one finds some alternative way for knowledge transfer. Till then, we need a flexible school where every individual student can find himself. As Editor-in-Chief of Today's Engineer pointed in [Gay01] "There is no such person as the average engineer. ... Some are more creative and innovative than others. Some are more systems-oriented. Some are more

entrepreneurial. ... The engineering profession needs all of us ... the tomorrow-thinkers as well as those who focus on getting today's work done."

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