HOLISTIC APPROACH TO TEACHING ELECTRICAL ENGINEERING? – PERSONAL VIEW)

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Abstract
The paper discusses my personal experiences with teaching Fundamentals of electrical engineering at University. I discuss the problems related to the efficiency of the teaching process. It is related to the state policy as well as to the technical advances we are experiencing. In the past the teaching was quite rigid and mostly with chalk and blackboard. Nowadays we are surrounded by technology advances which bring some difficult decisions regarding inclusion of modern technology to the teaching process. I show my personal experiences with the use of this technology, preparation of quizzes, additional learning material, real and virtual experiments, etc. The final objective is that the teacher should become more like a mentor, a guide or an instructor that helps the students to acquire appropriate learning skills which leads to future tasks of preparation of suitable learning material based on individual needs and capabilities.

1. Introduction
Teaching styles (approaches, strategies, etc.) are changing with time. The choice of selecting a suitable one depends on several factors. In this contribution I will discuss a personal view of teaching experience by looking at the past (the way I was taught), the present (the way I teach) and the future (the way I would like to teach or the way we will be forced to teach in the future). All this is related to my position as a professor of electrical engineering at the University of Ljubljana, Faculty of Electrical Engineering, where I am responsible for the classes Fundamentals of electrical engineering I and II at the four year program leading to the degree Diploma Engineer (similar to BE or Beng). (We also have a “classical” five year program leading to a degree University Diploma Engineer (MEng)). This is a major subject the students have to pass in their first year of study and is currently composed of four teaching hours a week, two hours exercises a week and two hours of laboratory work a week.

Several important factors contribute to the efficiency of the teaching process. Some of them are related to the (educational) state policy as well as the political/economical position of the country. The most important factor influencing the teaching process in Slovenia is that up to now the students did not have to pay for their university studies; they have full medical security, subsidized food, etc. They also have the possibility to earn some money by so called student work for which, they pay much less tax than the regularly employed workers. All this results in the fact that almost all the population that finishes secondary school applies for some kind of university study even if they are not really interested in passing exams – just to take advantage of the privileges. As a consequence the number of programs and faculties has significantly increased in the last ten years; especially, since the public universities and also some private ones are fully paid by the state depending mostly on the number of students that enroll in the course (and to some extent on the number of those that succeed in graduating). All this contributes to the possibilities the teacher has to organize an efficient and high quality course. Another important fact that influences teachers’ involvement in improving teaching methods and materials is the fact that teaching status (from junior professorship to full time professorship (tenure)) is related to the amount of research work and not to the quality of teaching – time spent to improve teaching methods, teaching material, etc.

2. The Past
This happened to be almost 20 years ago. The interaction between professors and students was more or less possible only during the lectures and at the final oral exam. The lectures were based on explaining the theory and taught with chalk and speech. Equations, derivations, sometimes an example or two were given. Usually, in order to increase motivation, some jokes were infiltrated in the lectures. (Some professors were known to have the jokes written in their lecture material so each year at the same time (lecture) the same joke was heard). In some classes transparencies

were used instead of the chalk. In general we students disliked this approach as it was basically used instead of the chalk and not to show additional (motivational) material. Besides, the derivation came too fast and it was not possible to understand and memorize the topics.

There was a written and an oral exam. In the written examination one had to mathematically solve a few given “problems”, while in the oral exam derivations or some basic understanding was required; mostly also through mathematical reasoning. At the end of our studies we students felt we were incapable of any practical work, although we had some theoretical knowledge.

3. The Present

Teach as you have being taught. This is a first and quite natural step. We use the material that is known to us and use the methods that we have already experienced. Although technology moves very fast the basic theories do not change much. Electromagnetic theory was set up more than 100 years ago and is still more or less unchanged. What is different is that today time is “passing much faster”. Not in terms of physics, but in the way we experience life. This leads to optimizations and instant solutions. The students that leave university (graduate) are supposed to be “ready to go”. Their knowledge should be directly applicable to the industry. They should also be able to communicate well, work in teams, etc. So the demands of the employers have increased in the sense that they expect the graduates to be able to immediately cope with all the tasks they are given and effectively solve them. They are required to have also additional skills besides technical competences. In fact, the expectations of the employers are quite different from what the teaching at the university is basically oriented at: towards solid theoretical - technical competence. The university teachers usually have no experience with teaching methods, learning styles, etc. We are not required to be actively involved in some kind of educational process for improving pedagogical skills. Each professor is left to his own judgment how to teach and which teaching styles to use.

Modern technology resulted in the fact that all classrooms are equipped with some kind of information technologies (usually a computer connected to the internet and a projector). This has lead several lecturers to use Powerpoint (computer) presentations instead of using a blackboard and a chalk. So technology has only conveniently replaced the “hard-core” approach, the texts and the figures are much more presentable (nicer ?!), etc. The reports of students, as well as several scientific studies, have clearly shown that electronic presentations should be carefully prepared with proper timing (not too fast) and adequate content (not too much material).

The challenge of a modern teacher is to choose a suitable teaching approach and proper strategies and to be able to find and use suitable teaching materials. The choice basically depends on the knowledge of different teaching/learning approaches and strategies (theoretical and practical), prior experiences and objectives.

My first objective was to increase the motivational content of the lectures and the teaching/learning material. For that purpose I wrote and provided to the students the teaching material as a script that can be downloaded (for free) from the internet site (see for instance http://lbm.fe.uni-lj.si/oe/OE1_2008/OE1.htm, currently only in Slovene language). The teaching/learning material includes some additional links to interesting internet sites, some additional historical notes or some application notes, interesting research results, etc. This enables the students that want to study the topics discussed in more detail to have some additional guidelines and suggestions.

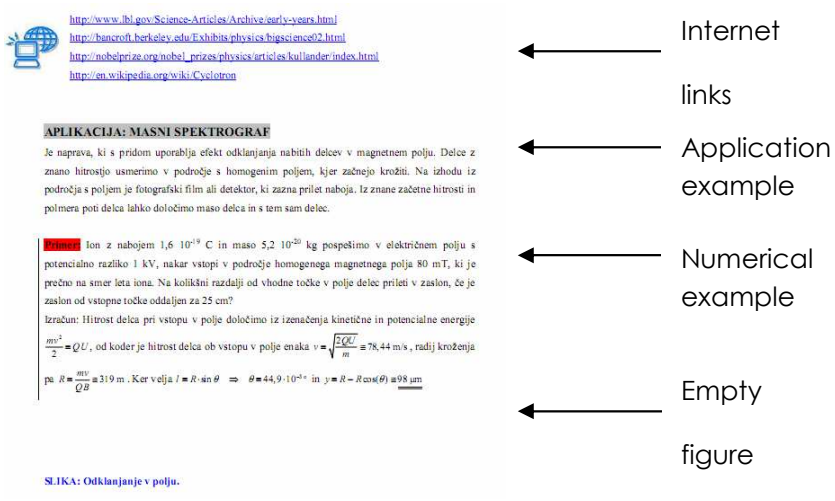


Figure 1: Example of teaching/learning script that is free for downloading.

I frequently use Matlab as a tool to solve and visualize the outcome of the solved problems. Matlab (or Octave, Freemat, etc.) is not systematically taught in the first year of study (although in my opinion it should be) so I make a short introduction and also provide some additional supporting material for those that like to explore further. (It is true that an immense amount of material for learning Matlab exists on the internet but in my opinion it is advantageous to make the first steps in Matlab as a working tool for electrical engineers smoothly and directly oriented to the problems related to the topics discussed during lectures). The script includes some basic Matlab sentences to solve concrete problems.

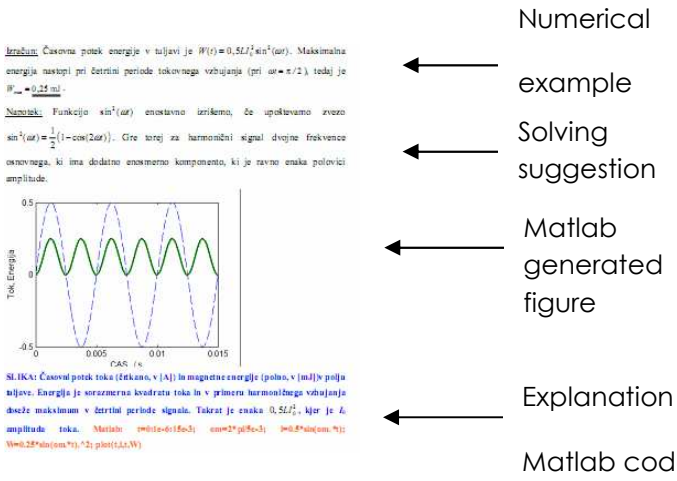


Figure 2: Another page of a script with solving suggestion and Matlab generated figure with Matlab code.

The script does mostly not include the drawings but there is an empty space with a figure title and explanation so that the students can draw the figures from the blackboard at the lectures or later complete the script from their notes. One good reason for not providing the figures in the script is that the students are “forced” to attend the lectures and the second one is that the students usually copy the figures from the blackboard to their notebook but not much from the spoken “material”. The script also includes some (mostly simple) demonstration exercises. This is essential as the students entering the four year program mostly come from technical secondary schools. Most of them have difficulties in abstract thinking and have insufficient mathematical skills.

I made some attempts to ease their lack of mathematical and foremost learning skills by providing additional testing questions that include mathematical assignments as well as theoretical questions. A web application (using freeware from http://www.lucagalli.net/) is used for this purpose that enables them to exercise and track correct and false answers. At the same time the

application allows a teacher (myself) to track the amount of time spent on the task as well as correctness of the answers.

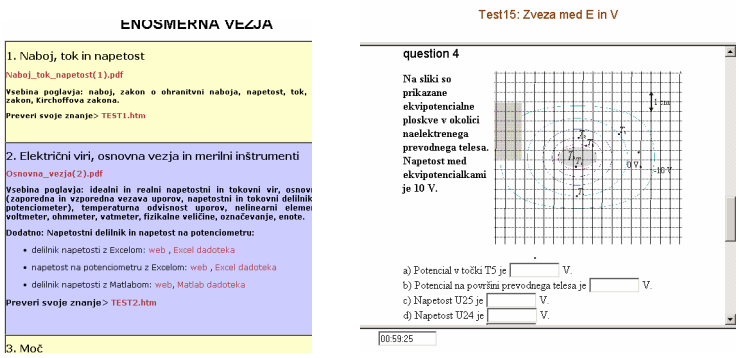


Figure 3. Left: Web page with script pages divided according to the content with added Matlab or Excel code as well as link to the web based test questions. Right: Example of web based test questions.

It was a big disappointment when it turned out that most of the students did not use this opportunity. I found several reasons for their not making use this possibility:

- Most of the students are not motivated to do regular work. They usually wait until the time of the exams when they study more intensively just for the occasion.
- The students are not motivated as this task does not result in any grades or is not a part of a final grade.
- They do not see why solving additional problems would be beneficial to them. The benefit should be instant and not abstract.

In order to increase the use of this material I included it in the final (oral) exam. The students immediately recognized that it will be beneficial to them to know the answers to the questions from the web based quiz and acted accordingly. Consequently, the use of web based quiz exercises significantly increased.

It turned that out the students are unaware of the importance of the learning material for their further studies or practical work. A common remark of the students is “where will I use this knowledge” or “where is this theory used”. An answer to this question is not always straightforward. One cannot directly have an answer to the question where I will use the Gauss law in practice, while the law is a fundamental law of electromagnetics. Furthermore, it is hard to convince students that infinitesimal and integral calculus is fundamental to understanding basic physical (electrical) phenomena and they have to be used to solve frequently even simple problems. I have used two approaches to tackle this problem: one is to devote more time to an explanation of what the integral is and what it is good for, where it should be used, etc. (similarly for the infinitesimal calculus). (The students are supposed to know these things from secondary schools but due to big differences in the quality of the schools the knowledge of these topics is very diverse). The problem of what equations are good for I try to explain on “real world” examples. For instance, we discuss how things work, how they are designed and which parameters of the device are of paramount importance for device operation.

Our experience from laboratory work (that is obligatory) shows that the students are mostly not fluent in speaking about the discussed topics, neither have they solid writing skills. Due to a large number of students (cca 150) it is difficult to have more student-to-teacher discussions so we decided to improve the students writing skills by making obligatory individual short seminars the students have to provide (deliver) at the end of the year. In a seminar the students work on a topic of their choice but it has to be related to the topics discussed at the lectures. A template is provided with some requirements such as: the seminar should include at least one equation with explanation, have appropriate citation of the literature used, cite at least one book, one (scientific) article and one internet source. The students mostly delivered the seminars in the “last minute” but

without much disapproval. In fact, some of them liked the freedom to choose the topics and handed in some solid material. The most difficult problem turned out to be appropriate incorporation of an equation (equations) and its suitable explanation. This shows the disability of the students to do some theoretical (mathematical) reasoning and to use it in a suitable manner. So there is a big difference in having a slight idea of how the device operates, in knowing which fundamental laws contribute to its operation and being aware of the (design) parameters that are of paramount importance for its work.

I frequently conduct some genuine (real) experiments during the lectures. These are specially made for teaching purposes so they nicely show the discussed physical (electrical) phenomena. These "shows" are appreciated by the students. They ease the discussions on the subject and make the lecture more "dynamic". I also believe the students become more concentrated on further theoretical (mathematical) explanations of the discussed topics. So the inclusion of real experiments as well as real working devices (apparatus) has turned out to be an important factor contributing to the teaching success. As a consequence we will have to work further on more inclusion of real experiments in the lectures.

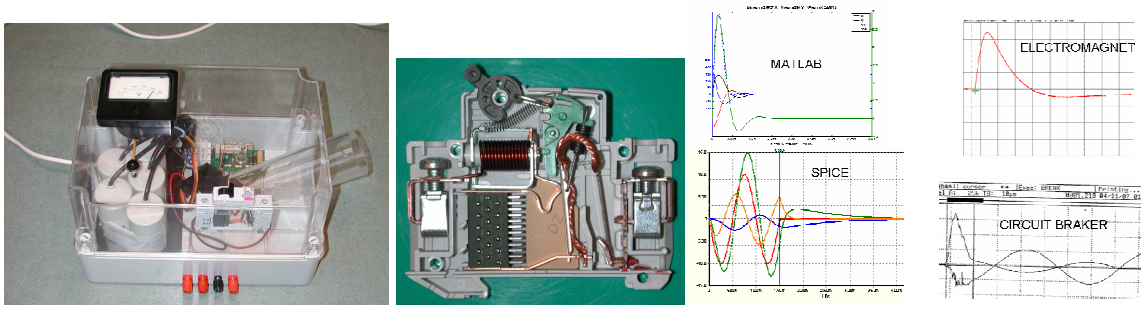


Figure 4: Left: electromagnetic gun and a circuit breaker as a real experiment for discussing some device operation. Middle: circuit breaker. Right: comparison of numerical and experimental data.

I also frequently use computer animations and virtual experiments. The reason is basically motivational and also to improve understanding of the topics. I found computer visualization absolutely necessary, as we also have to be aware that the students will use the computer tools in their practice. So we can present the results of computer simulations with the software tools that is also used in practice for the design of electrical devices (for instance Matlab for different kind of solutions of mathematical problems, Spice for simulation of electrical circuits, some tools for simulation of electromagnetic phenomena (Comsol Multiphysics, Maxwell, etc.).

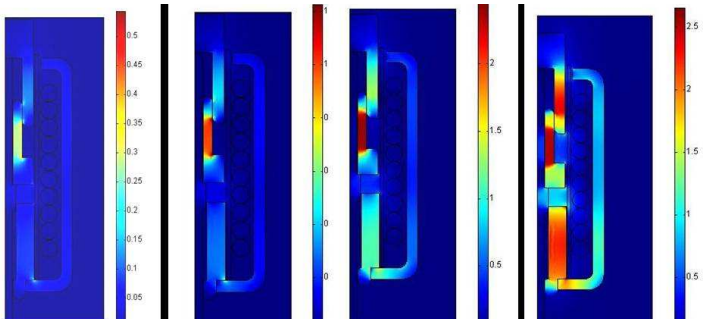


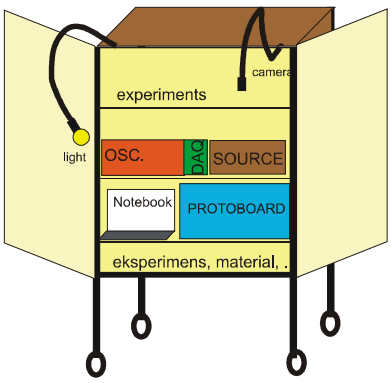
Figure 5: Simulation results of a electromagnetic circuit braker; increase of magnetic field density with increased current injection can be observed.

In order to increase the interaction between the students and the teachers/assistants we organized a web based Forum. This has turned out to be a convenient tool although it is mostly used for exchange of information on exams and solutions to some problems after the end of the lectures t.i. in the period of the written and oral examinations. Some attempts have been made to motivate the students to write in the Forum of some interesting topics found on the internet but not with much success.

The bottom line is that we have to provide means to increase students' motivation for better comprehension of the teaching/learning material. Whether the teaching must be of inductive (problem based, discovery based, …) or deductive (from fundamentals to applications) is not so important or better, it should be both. All in all it should be dynamic, using different teaching approaches that "surprise" the students and give them a sense of an experience, a "show". So from my point of view deductive teaching is important but should be combined with inductive so that the students have a broader sense of the topics discussed and a better understanding of the material taught.

4. The Future

The Future is largely unknown as it does not only depend on our (my) involvement as a teacher but also (as discussed in the introduction) on the educational state policy and the social status of the students. Concerning the state policy I think it will lead to some student participation in covering the cost of university education. This could help in increasing the motivation of the students in the learning process. Additional motivation can be gained by providing high quality teaching/learning material. I am thinking of constructing a kind of experimental (magical) box with pre-prepared experiments and a simple possibility of inclusion of information technology and measurement equipment.



Some of the learning material has to be prepared for more advanced use of information technology. This could enable better interaction between the teacher and the student especially in terms of simultaneous track of understanding of the learning material. The students will be "forced" to spend more time on solving problems that will be individually prepared and on-line driven according to their abilities.

The objective is that the teacher becomes more like a mentor, a guide or an instructor that helps the students to acquire appropriate learning skills and suitable prepare individual based learning material for them. The mentor should provide evidences of the importance of the learning process. For this purpose he (myself) should be well prepared and have high quality teaching material from various sources. It is important that the teacher has personal experience in at least a part of the topics that he discusses. This experience can derive from his occupation with basic or applicative research or research directly devoted to providing high quality learning material.

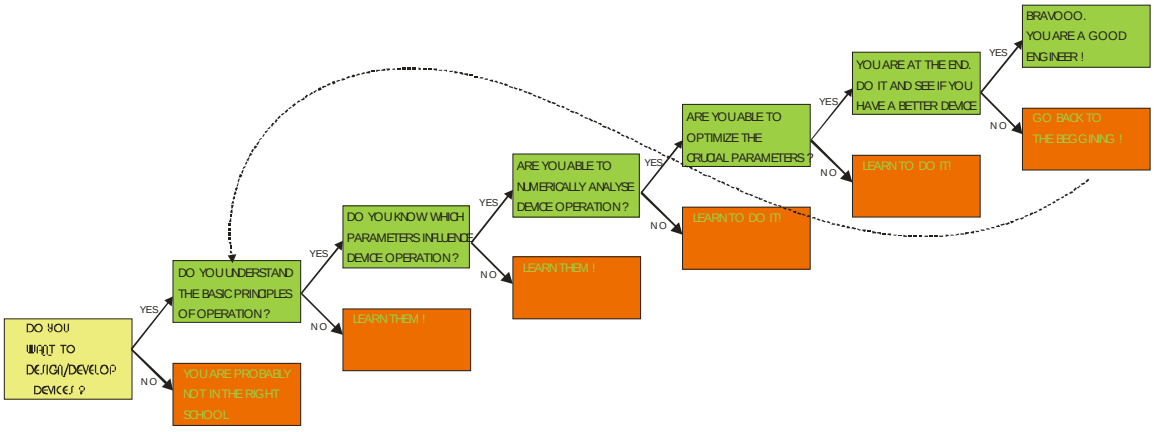


Figure 6: a chart that a student and a teacher has to keep in mind and follow it in order to come to the final goal: to be able to understand basic underlying principles and from them be able to analyze, optimize and design new devices.

5. Conclusions

To conclude, I have provided some thoughts about personal experience in teaching electrical engineering at the university. Due to the educational state policy and other factors most of the students entering University studies are not skilled in mathematics and neither in verbal or written

communication. Furthermore, they are mostly unmotivated for studying but somehow motivated in obtaining good grades (passing exams). Their interest is increased if virtual or real experiments are included during lectures. This dictates the current teaching style that should provide ways to persuade students to work harder. Information technology offers tools for individualizing studies that should include motivation by providing reasons for the necessity of learning. There is no end to this story.

6. References

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