Problem-Based Learning Applied to Electrical Engineering

E. Helerea, A. Maţoi, I. Oltean, A. Munteanu
Transilvania University of Braşov/ Electrical Engineering Department, Braşov, Romania

Index Terms: Electrical engineering education, Problem based learning, Designing.

1. Introduction

The current debates with respect to the role of the education, of the schools and of the universities within contemporary society, focused on the targets of the education and on their relation with the human being, with society and culture, comprise questions of importance, such as:

- Which are the competencies of priority?
- What does education stand for: instruction, socialization, knowledge transmission?
- How will education look like in the perspective of the automation, of the globalisation and of the internalization of society?
- Which is the role of the universities and of the university education?

The answers are multivalent and the Bologna conference, as well as the actions following this one circumscribe in the sphere of these preoccupations: the schools, the universities play the part of motor for the development of society and the reforms enhance this desideratum. The educational policy aims at fighting against the fears that in relation to the requirements and to the tendencies in the future there should be a diminution of the training quality. There are severely criticised and enhanced the limits of the training in relation to the necessities, on all levels and forms of the education.

As regards higher education, here, too, because the administrative resources of higher education institutions become more and more limited, the teachers must expose the scientific contents to a greater number of the students. On the one hand, it is obvious that in these conditions, the direct communication between teacher and student becomes even more difficult or even impossible, and the quality of learning process could decrease [1] [2]. On the other hand, in the conditions of globalization and of the development of a society based on knowledge, for the graduates, as active members of society, new tasks are required. It is also important to add that, in a continuously changing world, the lectures given *ex catedra* do not attract the student anymore.

These aspects are important for engineering education, particularly for electrical engineering education, where the challenges in new fields as power engineering, control engineering, electronics, microelectronics, signal processing engineering, telecommunications, instrumentation engineering, computers, are major. To develop the professional competences and the moral profile of *Homo Technicus Eminens,* education must have in view the new didactical strategies in which *what*, and *how* should be in multiple connections with the new contents of pure and applied sciences, scientific research, and economical, ergonomic, moral, philosophical aspects of real world [3] [4] [5].

The Higher Education is now involved in a real educational reform, in which **active learning** is the central axis. New policy and strategies are proposed and new methods of the teaching-learning-evaluation process are taken into account, both for teachers and students, in order to save time and to make the process efficient. New Challenges in Engineering Education also appeared.

In the paper there is done a comparison between the traditional and interactive method.

2. Interactive methods in the teaching -learning process

In comparison with the situation of a traditional learning in which the teachers expose or read the lectures as emitters and students are passive parts as receivers, without any feedback, the active learning takes into account the students and their learning needs, as the core of the system. The synergetic effects are produced if the students are the **active partner** of the process: they use the learning resources through reading, writing, talking, listening; they reflect on phenomena and processes, they can ask questions, evaluate the results, consolidate the new knowledge and apply the information to the special field.

In **active learning** many strategies are proposed [6][11]: individual activities, peer activities, informal working groups, cooperative-formal working groups, etc. The role of teacher/tutor is essential in establishing the type of strategy – depending on the number of students, environment, spatial location, objectives of

syllabi/curricula, and the criterion of time. Some strategies recommend that lectures should not be abandoned– the traditional and active methods could be combined, adding new values to the evaluation process of teaching and learning. A comparison between the classical and modern methods clarifies the specific characteristics (see Table 1, Table 2).

Table 1. Comparison between traditional and active learning.

Traditional learning	**Active learning**
Lectures	Work in tutorial
Knowledge transfer	Building the knowledge
Syllabi	Defining the objectives
Theory and concepts	Conflict-situations/ problems
Knowledge acquisition	Skill to learn
Deductive thinking	Inductive thinking
Memorizing lectures	Finding the information
Individual work	Work in group
Exams	Self-assessment /Formative evaluation

The **interactive methods** are oriented on new centres if interest, such as: group discussions, problem-based learning, case studies, role interpreting, structured study groups, etc. It is foreseen that computer and video-techniques would represent more attractive teaching methods.

Table 2. Comparative characteristics for the traditional and for the interactive methods of teaching-learning-evaluation.

Traditional methods	Interactive methods
There is much taught, little learnt	*There is much learnt, little taught*
Magistral lectures	Tutorship in workshops
Knowledge transmission	Knowledge building
Analytical syllabi	Defining the objectives
Theory and concepts	Problems/Situations
Knowledge acquisition	Skill to learn
Deductive thinking	Inductive thinking
Memorizing the lecture	Searching for the information
Individual work	Work in group
Exams	Self-assessment/Formative evaluation

The interactive methods are close to the research methods (Table 3).

Table 3. Comparison between the interactive learning methods and the scientific method.

Scientific method	Interactive instruction methods
Preliminary observation	Clarifying the problem-situation
Elaborating a set of problems for the research	Defining the problem and the set of questions
Choosing the hypotheses	Choosing the hypotheses
Settling the experiments	Settling the learning objectives
Collecting experimental data	Collecting information, documentation
Checking the hypotheses	Checking the hypotheses
Complementary experimentations	Supplemetary documentation

The two methods are comparable:

- The students learn to use the knowledge within a professional context and to adapt the solutions to a given situation;
- The students participate in an active manner to finding a working practice;

The two methods have the same pedagogical approach:

- They optimize the learning conditions;

- They benefit from the interactivity and the interdisciplinarity;
- They favour the self-teaching;
- They adopt a professional approach;
- They encourage the professional development (creativity, autonomy, responsibility).

They have the same work stages:

- Setting the teams;
- Determining the problem situation and elaborating the theme /the problem or the project;
- Assigning the tasks and the terms;
- Individual work;
- Team work;
- Project/report drawing up.

Assessment/self-assessment and final evaluationwhich may be:

- Realizing a study in a professional manner,
- Drawing up a report / memorial/ and defending it,
- Adopting the formative evaluation and the self-assessment,
- Systematic evaluation and improvement of the working method.

But, these new working methods require proper training and appropriate skills for both teachers and students, and especially the ability to work in virtual environments. In this paper, the problem-based learning method is considered, and the specific steps used in designing the problems for electrical engineering education and implementing PBL method are presented.

3. Problem-based learning in engineering education

A short History of PBL method

Problem-based Learning (PBL) is an active method of teaching and learning, which transfers the responsibility of the learning process on the students. The method is based on the process of analyzing a conflict/problem - situation and clarifying the sources of conflict based on the previous and newly acquired knowledge. This way, the students have an active role in creating the problem, in analyzing and giving solution/solutions. This approach increases their responsibility for learning and motivates them.

This new approach started in medical schools in the late 1960s. The concept of PBL, introduced by Howard Barrows [12]-[15], was widely disseminated and implemented.

In 1992, several professors at the University of Delaware began adopting and adapting PBL methods for undergraduate instruction in both introductory and advanced courses in a number of subjects.

This approach is useful for engineering education and can easily apply to it. But, some difficulties still exist, for in engineering education the problem solving is a method generally and widely used and certain confusion could appear when associating it to PBL method [23].

Many European universities began applying this type of active learning by using the interactive method [16]-[19]. In 1974, the University of Aalborg – Denmark declares its educational strategy in using problem-based and project-organised learning as a teaching model [20]. The model is applied now in all study programmes of the Faculties of Humanities, Social Science and Engineering and Science. In 2000, the Catholic University of Leuven – Belgium launches *Candis 2000* project, in which the innovative method of PBL is to be applied in building engineering education [21]. The Universities of Maastricht, Paris 7 – *Denis Diderot, Louis Pasteur* University of Strasbourg and many others have proposed training courses for teachers and tutors as to get skills in designing and implementing the PBL method.

Some projects in education are also sustained and supported by the European Union, as appropriate means in modernising the system of education. [22].

The Leonardo project *COMPLETE* [24], in which five European universities are involved – *Transilvania* University of Brasov, Gent University, Paris 7- *Denis Diderot* University, *Louis Pasteur* University of Strasbourg, and *Uninova* of Lisbon – also sets out to introduce innovation in using the interactive methods – Problem-based Learning and Project-based Learning – applied to engineering education. The teachers as trainees attend specific courses and they learn how to design the processes, how to assist the students to promote thinking and discussion, to establish and maintain positive group dynamics, and to provide the students with new resources. An e-platform sustained this innovative approach, applied also during running the undergraduate study program in Electrical engineering and computer science, from Transilvania University of Brasov.

The experience gained in this project proved that the efficiency of the PBL method largely depends on the modality of scenario design, preparation and implementation [24]-[26].

The steps for PBL method designing

The steps for designing the PBL scenario in engineering education consist in the following:

1. Establishing the PBL team of teaching staff;
   - They "scan" the whole course to select parts that will be best served by PBL;
   - A teacher-coordinator of the whole course is established, and more teachers are selected/elected for each sequences;
2. Studying the different parts of the course
   - The teaching staff proposes the way/modality of working;
3. Preparation of the support material for the students' work;
   - The teaching staff notes the selected bibliography and documentation resources (books, reports, magazines, software, websites, etc.),
4. Selection of the tutors;
5. Choosing/designing the lab facilities (if is necessary);
6. Defining the agenda;
   - Dates of the group meetings,
   - Dates of the tutors/students meetings,
   - Date of the report/project delivery,
   - All the teachers involved agreed on the agenda of the course;
7. Preparing the ways for a good communication
   - The teaching staff assured different way for the groups of both teachers/tutors and students.

Some remarks should be made:

- This step asks a lot of discussions on the content of each proposed problem/project;
- It is time-consuming to establish the scenario, and to sustain the students in asking the good questions and finding the proper answers, and to evaluate the study results;
- In this step the modalities and didactical materials are established: bibliography, lectures, tutorials, case studies etc. (Fig.1).

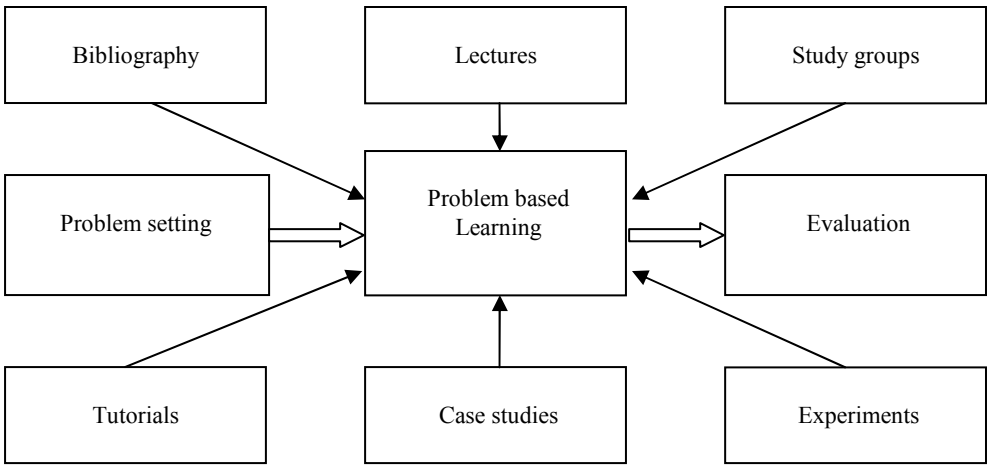

Fig.1. Some elements for implementing the PBL method.

The steps for PBL method implementing

In order to implement the PBL method the steps followed the learning process: it opens with the exposition/setting of the problem situation - the students are invited to discuss among them starting from a problematic situation from real life; they ask the questions, and some of the questions are the learning objectives themselves;

The analysis of the problem will lead them to the learning objectives. Thus, the acquired knowledge is re-activated and the students are motivated to find answers to their own learning objectives, through a dynamic and independent work. The problem solution/solutions prepare the students to think in a critical and analytical way, and to find and use appropriate learning resources. They can use biographical resources, participate in lectures, use case studies, experiments, and Internet resources (Fig. 1).

The actors involved in this process are: teachers, tutors and students (Table 4), each of them having specific responsibilities:

- Teachers - introducing the concept and rational use of PBL problem within the course/module and defining the scenario;
- Tutors - guiding the student and assuring the dynamics of student groups;
- Students – as active part in acquiring and producing knowledge, they have a key role in the group once defined: there is demanded the role of a leader, a scribe and a speaker.

The group of the teacher and that of the tutor have the main responsibility in problem designing and implementing.

In the process of implementing the PBL method, the important questions should be solved:

- How to choose an appropriate situation/problem?
- How to present the situation/problem?
- What kind of learning resources should be used?
- How to apply the facilities of information technology?
- Is it necessary to solve the problem?
- How to validate the learning outcomes?

All these questions are challenges for teachers /tutors, and they should find the efficient ways of solving them.

As a field of research, PBL is still in the development stage. For example, there is not sufficient research or empirical data to state that PBL is a proven alternative to other forms of instruction [21]. But, based on evidence data over the past ten years, PBL appears to be a better model for producing gains in academic achievement, although the results vary with the quality of the project and the level of student engagement.

Also, it seems that PBL is not appropriate as a method for teaching basic skills such as reading or computation. Data show that PBL enhances the quality of learning and leads to higher-level cognitive development through the students' complying with complex, novel problems [27]. Accomplishing these goals, both teachers and students have to master the strategies necessary for designing successful PBL.

Table 4. Steps, phases and actors in PBL method design and implementation.

Main steps	Phases	Actors
I-Teacher group	Making a scenario according to learning objectives	Teacher
	Defining/creating the situation problems	Teacher
II-Tutor group	Presenting the situation-problem	Tutor
III-Group work	1. Identifying and clarifying the terms	Tutor and students
	2. Defining the problem and drawing a list of processes to clarify	Tutor and students
	3. Analyzing the problem and emitting/proposal/ the hypothesis	Tutor and students
	4. Systematizing the hypothesis	Tutor and students
	5. Clarifying the learning objectives	Tutor and students
IV-Individual work	6. Individual study	Students
V-Validation the knowledge	7. Systematizing and validating the solution and the hypothesis	Tutor and students
	8. Tutorial evaluation	Tutor and students
VI-Self-evaluation	9. Self and peer evaluation/ Individual balance/efficiency of the results	Students

The relevant and engaging instructional models should be developed in concordance with learning environment.

4. Case Study – Designing a problem for electrical engineering

What kind of problem is there raised?

- There is raised a practical problem, from the real life, which covers the area of study proposed in order to be explored by the students;
- The chosen case has to be sufficiently well defined, with a clear and concrete objective, so that the students should be stimulated and motivated to search for solutions;
- The submitted case may be unidisciplinary, however the interdisciplinarity is recommended (comprising technical, economic, socio-cultural, ethical, legislative aspects etc.), being adapted to the course

attendant's/student's level of knowledge; this fact will allow the development and the further evolution of the problem thinking, in the measure in which there is acquired knowledge;

- There is recommended to raise problems that should allow different modalities for collecting the information (interrogation, noticing, experimentation) and that should present several variants of solutions.

The research indicate the stages that to be gone through in designing the *Scenario of a problem:*

Stage I: Determining the learning objectives,
Stage II: Determining the key words, which cover the area of study,
Stage III: Enunciation of the conflict situation:

a) There is usually presented to the students a conflict state/situation / a disequilibrium in connection with the economic background, security, environment, socio-cultural background, disequilibrium that has a few symptoms or groups of symptoms;

b) The situation of disequilibrium between the DEMAND and the OFFER may be presented on different levels of solving the issue .

Example:

- level 1: the users' demand for motor vehicles exceeds or is lesser than the offer/capacity of circulation in the road transport;
- level 2 (it makes reference to the values that characterize the demand and the offer): the disequilibrium may be presented through the number of motor vehicles necessary for the transporter, which is lesser or greater than the number of sampling motor vehicles that circulate upon a road segment in the unit of time.

c) The enunciation of the conflict situation is adapted to local, practical, situations, such as:

In Brasov on Mureşenilor Street, there are currently taking place traffic jams.

The jam is a symptom of a disequilibrium whose main causes are to be set together with the students. Starting from these causes, the students will formulate their learning needs.

The enunciation for the problem situation will be easier to formulate if there is used a formal exprimation: *Although...., However...*

Although on the level of the city of Braşov, the number of motor vehicles has not increased dramatically during the last year, however on Mureşenilo rstreet there are currently taking place traffic jams.

Such an enunciation describes more eloquently the conflict situation, in whose solving the students are invitated to participate.

d) In the enuciation, there also have to be mentioned the students' tasks, such as:

We propose for you to determine:
a) which are the symptoms and the characteristics of this situation,
b) which are the causes,
c) which are the possible remedies/ modalities for solving them,
d) to define the general solution/problem in order to solve this conflict situation,
e) to determine the learning objectives,
f) after the documentation, resorting to the resources in the submitted subchapter and other resources indicated in this subchapter, fill up the dictionar of terms with the corresponding definitions for the submitted key words and others you have set
g) draw up the map of the concepts
h) draw up a paper that should describe the activity carried out and the solutions; the paper will be uploaded on the web page of the group and will lay at the basis of the evaluation of the group activity.

Stage IV: Drawing up indications for the tutor

a) The enunciation of the problem might be:

In order to prevent the apparition of the traffic jam, there has to be maintained the equilibrium between the demand and offer of transport, through the adequate correlation of the parameters of the road traffic.

b) The possible learning objectives proposed/set by the course attendants, together with the tutor:

- *To define the concepts of road traffic and road flux,*
- *To know the parameters of the road traffic,*
- *To identify the connection between these concepts.*

c) Map of the concepts

The map/the graphic of the concepts has to link in logical connection the clarified concepts and the connections among these ones.

d) Group paper

It has to comprise all required elements, with the observance of the time graphic submitted for PBL.

e) Planning the activities

It is carried out by the tutor, who sets the number of face-to-face necessary meetings and the total working duration.

In electrical engineering, as in any field of education, a good problem for PBL method implementation has to have the specific characteristics:

- to be engaged and oriented to the real world,
- to generate multiple hypotheses,
- to require team effort,
- to be consistent with the desired learning outcomes,
- to build upon the previous knowledge and experience,
- to promote development of higher order cognitive skills.

Problem should follow-up

- Resources to be identified and evaluated
- Summary of the problem
- Reassessment of the problem
- Group evaluation
- Knowledge abstract and summary
- Definitions, concepts, principles outlined
- Diagrams, lists, maps, flow charts generated.

With respect to these facts, in this paper a case study on designing the problem for PBL method and on establishing the best scenario for the implementation the PBL. A simple case in electrical engineering field is considered: the electric capacitor.

Motivation of choosing this theme:

- In electrical engineering, the **capacitor** is a good example of the passive component in which many electrical processes are developed. This is an opportunity to activate the old concepts and to discover new concepts in electrical engineering education. The tutor can use these situations to define the problems in which some **old concepts** can be activated (*Electrical field; physical quantities: electric charge, capacitance, electric energy; ideal capacitor*), and other **new concepts** should be developed and applied (*Static and Dynamic processes of charging and discharging, Real capacitor, Equivalent schema, Dynamic characteristics; Ageing of the materials; Reliability of the capacitor*; etc.).
- Many new technologies and manufactory techniques have improved the electric characteristics of the capacitors, so that the new applications have been proposed in different domains. One of the most exciting applications is the use of the capacitors for the electrical energy storage. The capacitor is also an important element for supplying the vehicles, for energy saving, or smoothing the peak voltage in power networks, etc.
- The students from the undergraduate courses in electrical engineering are interested in these problem-situations.

Designing the problem, having as field of application electric capacitor, follows the scenario in accordance with the strep of usual PBL process running:

I. Start meeting

The objective of the start meeting of the student group and the tutor is to expose the problem-situation, to analyze and to define the problem, to establish the learning objectives and the individual tasks.

- Problem-situation exposing: The tutor exposes the problem-situation

  Example: *Many electrical capacitors are used today for energy storage, but, the performance does not meet the requirements.*

- Problem-situation analyzing: The students ask questions to clarify the significant elements of the problem-situation, as:

  Example: *What is a capacitor? How is energy accumulated in a capacitor? What happens when electric voltage is applied? Is it possible to represent a real capacitor? Could the SPICE program be used in showing the charging process? etc.*

The students organize the questions and define the problem. Having in view that they are in the second year of the study program, it is most probable that they would choose as problems:

How to reduce the charging time for an electric capacitor? or

Does temperature have a great influence on the charging time? or

What charging-discharge characteristics are required for the energy stocking capacitors?

Together with the tutor they will give some explanations, by using the previous knowledge. Organizing the explanations and establishing the priorities will lead them to a reflection – synthesis of the possible mechanisms.

- Establishing learning objectives: The organization of the explanations by identifying the priorities, the connections between different mechanisms and the incertitude of explanations will allow them to represent the synthesis of the concepts as a diagram or a tree, which will define their own new learning objectives. These could be:

  To clarify the charge-discharge processes in capacitors

  To clarify what a real capacitor is

  To introduce different equivalent schema for a real capacitor

  To establish the mathematical model for different equivalent schema

  To apply the electrical circuit methods in finding the static characteristics, etc.

  The student group will plan the tasks for each person of the group and a list of questions/tasks is drawn.

II. Individual/autonomous study

The objective of this step is to achieve the learning objectives, to collect and to manage the information with the aim of problem explanation, and to acquire the competences and skills for an autonomous learning.

- Each student will use the biographical references, papers, readings, lab applications, and computer applications to find the explanations for the list of questions. The individual study is the most important step, and here, the tutor should give advice: in identifying the appropriate source of information, in offering suggestions, in facilitating the access to the computer programs etc.

The students should also use some computer techniques. For example, they can propose a simulation of the real RC serial capacitor supplied with various wave form of voltage, with a software as SPICE program.

This program offers the possibility to study the voltage dependency of the real capacitor and to obtain the charge characteristic of the capacitor, the influence of the temperature on the charge time, by modifying the material parameters of the capacitor. Solving this problem, new questions will be generated, like:

What is a step signal?

What is the significance of the time constant of the RC circuit?

What is the connection between the time constant of a RC circuit and charge time?

What is and for what a marker is used? Etc.

In this step, each student will note on the list of questions / tasks the plausible explanations and also the points of ambiguities.

III. Meeting for common use of acquired knowledge

This step has as objective to realize the balance of group, and to evaluate if the learning objectives are achieved. The students present the results of their individual study, interpret them and establish the final results. This step is important for the stability of the group, and for the working environment. Each student should also propose an individual result of the learning objectives.

The discussions will generate further questions. For example, from the RC circuit:

Is the time corresponding to the final voltage on the capacitor proportional to the external resistance R_{ext}?

Which is the connection between charge time and value of external resistance?

Which is connection between the increase of temperature and charge time?

These questions will generate other further problems/problem-situations, such as:

How could the charge-discharge times be modified?

The model used in Figure 2 does not allow obtaining voltage characteristics in the charge-discharge process!

During this meeting the students could build a map of concepts used in this problem, like in Fig. 2 and they could explain the connections, or to propose new connections

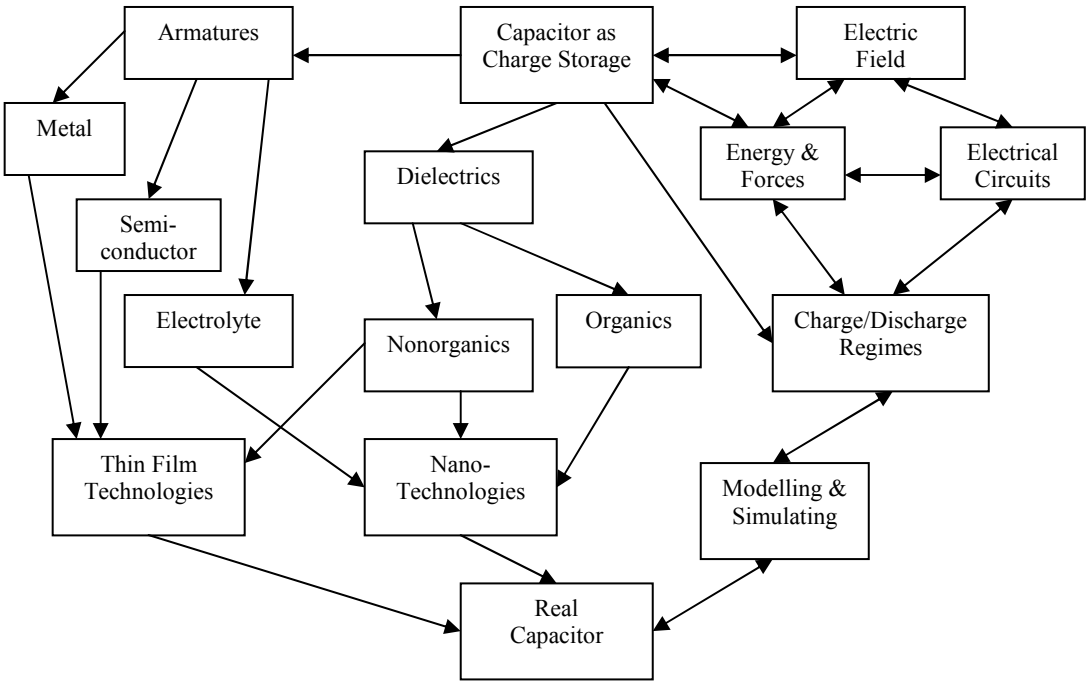

Fig. 2. Concept map for electric capacitor used for energy storage.

This problem was experimented and the results are the growing interest for this domain, and the acquisition of new knowledge and skills by experimentation and using software programs.

5. Conclusions

In this paper a comparison between the traditional and interactive method is done. Due to the evident advantages, in higher education it is a necessity to introduce new teaching-learning-evaluation methods. It is also useful and appropriate to incorporate and to apply to electrical engineering the interactive methods. The PBL is an attempt to create new instructional practices reflecting the environment in which students live and learn now. Different strategies can be applied, depending on several criteria: the number of students, special environment, and objectives of syllabi/curricula, time requirements.

The PBL model establishes the specific steps and responsibilities for the actors involved in this process: teachers, tutors and students. The model was implemented to the undergraduate study program in Electrical engineering and computer science from Transilvania University of Brasov.

The electric capacitor is a good example how different problems can be formulated and used in the PBL method implementation, and computer could sustain the solving problems and the generation of the new themes. Interdisciplinarity is the key word of this approach.

Acknowledgement

The research work has been developed in the framework of the project "CEREX – Models and Indicators for the Evaluation of Scientific Research in Universities in the Context of Knowledge Based Society", No. Cex 06-8-85/ 19.02.2006, granted by Excellence Research Program of Romanian Government.

REFERENCES

[1] *I. Makin, "SET for Europe: discovering tomorrow's challenge," Science, Measurement and Technology, IEE Proceedings A, vol. 136, issue 1, pp.16 –23, Jan. 1989.*

[2] B. Bilsel and O. Oral, "Role of education, science and technology in developing countries," *Frontiers in Education Conference,* Proceedings, vol. 2, pp. 4c4.11-4c4.14, 1995.

[3] G. Vasilca, "Personal view: Engineers for a new age: How should we train them?" *International Journal of Engineering Education*, vol.14, n.5, pp.394-399, 1994.
[4] K. Henderson, "Educating electrical and electronic engineers", *Engineering Science and Education Journal*, vol.6, issue: 3, pp. 95 –98, June 1997.
[5] Hagen, J. W. Wiesbeck, "Electrical engineering education in Germany," *IEEE Potentials,* vol. 19, issue 3, pp. 37 –39, Aug.-Sept. 2000.
[6] R. Morawski, R. Pallas-Areny, E. Petriu, M. Siegel, and T. Laopoulos, "Current trends on teaching instrumentation and measurement," *Instrumentation and Measurement Technology Conference,* 1999. IMTC/99. Proceedings of the 16th IEEE, vol.3, pp. 1715 –1726, 1999.
[7] C.A Marshman, M. Darnell, and D.J. Spikins, "A distance learning approach to EMC education and training," *Electromagnetic Compatibility, Eighth International Conference on*, pp. 271 –275, 1992.
[8] Z. Illyefalvi-Vitez, P. Nemeth, and B. Szikora, "Problem-oriented education of electronics technology at the Technical University of Budapest," *Electronic Components and Technology Conference,* Proceedings, No. 47, pp. 942 –950, 1997.
[9] V.J. Midwinter, "A question of quality [in electrical engineering education]," *IEE Review*, vol. 43, issue 2, pp. 66 –70, 1997.
[10] E. Helerea, I. Dănuț, L. Sofonea, "Some Consideration on Electrical Engineering Curriculum," *Proceeding of the 8th International Conference on Optimization of Electrical and Electronic Equipment*, Braşov, pp. 891-896, 2002.
[11] M. Popescu, E. Helerea, I. State, R. Niculescu, and S. Panțuru, "Reperes pour la projection des programmes pedagogiques – Instruments at methods," *Proceedings of the International Conference 25 Years of Higher Economic Education in Brasov,* pp. 380-386, 2005.
[12] H.S. Barrows and R.M. Tamblyn, *Problem-based Learning*: *an Approach to Medical Education*, New York: Springer, 1980, pp. 2006.
[13] H. Barrows, "A taxonomy of problem-based learning methods," *Med. Educ*., 20, pp. 481-486, 1986.
[14] H. Barrows, "Problem-based learning bibliographies", *http:www. eng.monashi.edu.au/pbl-1*, Nov.1995.
[15] Southern Illinois University. "Problem-Based Learning Bibliography," *http://www.siumed.edu/pblc/pblbib.html,* Jun 1996.
[16] D. Boud, and G. Feletti, *The Challenge of Problem-Based Learning*, New York: St. Martin's Press, 1997.
[17] R. Butler, D. Inman, D. Lobb, "Problem based learning and the medical school: another case of emperor's new clothes?," *Adv. Physical Educ*., vol. 29, pp. 194-196, 2005.
[18] ETE-Instructor Notes. "Goals and Objectives of problem-based learning" (PBL), *http://cotf.edu/ETE/teacher/tprob/teracherpbl.html*, Dec. 1996.
[19] *A Guide to Learning Engineering Through Pro*jects, 43/99PBLE: Project Based Learning in Engineering, University of Nottingham, Subject area: Engineering, http://www.pble.ac.uk, Nov. 2003.
[20] Kolmos, F.K. Fink, L. Krogh: *The Aalborg PBL Model- -rogress, Diversity and Challenges,* Aalborg University Press, 2004.
[21] Galand, M. Frenay, L'a*pproche par problèmes et par projects dans l'enseignement supérieur- Impact, enjeux et défies, Presses Universitaires de Louvain, 2005.*
[22] Ponta, G. Donzellini, H. Markkanen, "Network based project learning for engineering education," *Proceeding of the International Conference on Engineering Education*, Valencia, Spain, 21–25 July 2003.
[23] D.R. Woods, et. al., "Teaching Problem Solving Skills," *Engineering Education*, 66(3), pp.238-243, 1975.
[24] Helerea, A. Duta, et al., "Research & didactical projects - Creative ways in education - Transilvania University of Brasov case study," *Proceeding of the ICIE Conference of the 1st International Conference on Interdisciplinarity in Education* ICIE 2005, Athens, 2005.
[25] R. Farrow, and G. Norman, "The effectiveness of PBL: the debate continues. Is meta-analysis helpful?," *Med. Educ*., vol. 37, pp. 1131-1132, 2003.
[26] M.T. Moreno Alcázar, V. Landa Fitzgerald, "An Experimental Design to Study the Effectiveness of PBL in Higher Education", in: *First Year Science Students at a University in Peru*, South America, College Quarterly, Spring, vol. 8, 2005.
[27] Popescu, M., Helerea, E., Lupsa-Tataru, D., Neagoe, A. – Quality Assurance in Higher Education: Structures, Instruments, Actors, RECENT,.2005.